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BUTTERFLY LORE

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BUTTERFLY LORE

BY

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OXFORD
AT THE CLARENDON PRESS
London Edinburgh Glasgow Copenhagen
New York Toronto Melbourne Cape Town
Bombay Calcutta Madras Shanghai
OXFORD UNIVERSITY PRESS
Humphrey Milford
1923

'It may be said, therefore, that on these expanded membranes nature writes, as on a tablet, the story of the modifications of species, so truly do all the changes of the organization register themselves thereon.

'As the laws of nature must be the same for all beings, the conclusions furnished by this group of insects must be applicable to the whole organic world; therefore the study of butterflies—creatures selected as the types of airiness and frivolity—instead of being despised, will some day be valued as one of the most important branches of Biological science.'

H. W. Bates, *Naturalist on the Amazons*, 1863.

'The patterns of Butterflies' wings, once regarded with merely interested admiration, have become, in fulfilment of Bates's foreshadowing, the pages on which we can read the past history of the everlasting conflict between the hunter and the hunted, and the complicated process by which new forms have adapted themselves to changed and changing circumstances.'—*African Mimetic Butterflies*, 1910.

Printed in England

DEDICATION

To the lady whose scissors I borrowed many long years ago, in order to carry out certain crude and undirected investigations into the internal anatomy of a humble creature. Who, after regarding with puzzled amazement the development in her offspring of a taste for esoteric inquiry, overcame a natural feminine antipathy to undomestic pets, from snakes to sea anemones, which from time to time shared with her my early affections. Who was the prime mover in events which led to my receiving a serious scientific education, and who at a crisis in my life made it possible for me to abandon uncongenial paths and return to an early love. Who takes a rather mystified pride in my strange investigations quite out of proportion to their insignificance, and who answers cheerfully to any term of endearment, though known to those of less intimate privilege as my Mother.

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FOREWORD

'He was a peaceful old gentleman who collected butterflies.' The sentence is quoted from a novel which was popular not many years ago, and summarizes a common enough opinion of a pursuit which even a learned judge in open court has lately described as infantile. At the best the study of butterflies is frequently regarded as a suitable occupation for children, and a harmless eccentricity in old age.

There are undoubtedly a few collectors the depth of whose study is little more than pin deep. It is equally certain that few of our friends who profess an interest in the contents of a cabinet have any idea of the wonders associated with the beautiful veil of painted wings, whose very splendour tends to obscure the story of romance which lies behind them. It is a story of tragedy and of comedy, a history of an age-long and not always successful battle for existence, a tale of Nature's cunning in the employment of devices perfected long before Man himself existed. One page in this chronicle of marvels tells of such juggling with the mysteries of light and pigment as results in colours which no human artist can imitate; another, of the development of weapons as subtle and delicate as the surgeons instruments; another, of devices for concealment beside which the invisible princes of fairy

tales seem crudely conspicuous. All these wonders, and more, exist in the apparently inconsequent world of butterflies.

It must not be supposed that butterflies are in such ways more remarkable than other insects. Insects generally have become by far the most successful of all creatures. The number of their species greatly exceeds that of all the other animals in our world, and few, indeed, are the conditions and surroundings to which some of their forms are not exquisitely adapted. But unless we decide on some limitation of the forms to be studied, the record of their ways would be embarrassingly long. Two questions are constantly asked of the student of insects. The first comes from the materialist who sees no value in knowledge void of practical application. 'What is the *use* of such study?' he asks. This is not the place to describe the benefits which have accrued to mankind through the study of insects. The control of some of our most fatal diseases has been made possible by the work of the entomologist, while the debt of agriculture to the same despised worker can hardly be estimated. To the uninitiated there may seem little connexion between insects and engineering, yet if the Panama Canal possessed a coat of arms it should bear, not the device of great engines of excavation, but the figure of Science triumphing over a Mosquito. But even where no direct human benefit results, is there no beauty in the pursuit of knowledge for its own sake? 'For myself (said Darwin) I would however take higher ground, for I believe there exists,

and I feel within me, an instinct for truth, or knowledge, or discovery, of something of the same nature as the instinct of virtue, and that our having such an instinct is reason enough for scientific researches without any practical results ever ensuing from them.'

The remaining question comes from those whose narrow outlook regards everything in this and in other worlds as in some way expressly designed for the use and benefit of themselves. Confronted with the existence of creatures whose activities interfere with their health or comfort, they demand in half-incredulous astonishment, 'Why were these things made?' The bare existence of creatures which do not minister to their happiness is, to these people, a sort of blasphemy, a melancholy proof of the existence of a personified evil spirit, inscrutably suffered for a time to work his will. They are incapable of understanding that the world belonged to these forms of life before ever a man appeared upon it; that the stupendous scheme of Evolution, whereby living creatures have developed their beautiful adaptations, does indeed favour for a season one animal at the expense of another, but that the power of variability, through which each creature may in turn gain the ascendant, prevents any one of them from gaining entire control. Man is physically no more favoured than the rest of living creatures. In Nature the caterpillar and the malarial mosquito, even the malarial parasite itself, live their lives as regardless of man's convenience as they are unconscious of his existence.

I am constantly asked why interesting details of

insect life cannot be set forth for the benefit of those unaccustomed to the language of Science.

They see (to use a naturalist's words) 'the very entrance of Knowledge guarded by a hostile Language, which must be vanquished in single combat before they can enter; and they turn away in despair'. The present work endeavours to meet this too common reproach; it is an attempt to place in the hands of the general reader a simple, yet sufficient, account of some of the more interesting features in the structure and life-histories of the insects of which it treats.

Those engaged in research are too often pictured by their friends as living in a dry and unromantic atmosphere of Latin names and unfamiliar words. They are commonly supposed to occupy their time in arranging interminable specimens in endless rows, themselves dead to the human interest which their captures once presented.

Such a view is far from the truth. The ordering and preservation of collections are but means to our ends. By far the greatest interest lies in the observation of the habits of the living creature, or its structure. 'The best collections are those which enrich the mind by making it a store-house of Nature's marvels.'

When the work was first undertaken it was thought that there would be a difficulty in condensing the necessary material into a volume of reasonable size. This difficulty soon disappeared since it was found that many subjects of which much might have been written were of a too exclusively scientific interest to form part of a purely

popular treatise. Indeed, there has been some sense of disappointment that much has had to be omitted lest the purpose of the work be jeopardized. What remains must be regarded as a lifting of a mere corner of the veil. Should it interest the general reader it will have fulfilled at least a part of its purpose. If even a few of those into whose hands it may fall should be induced to pass on to more abstruse researches and so help further to advance our knowledge, it will have more than justified its existence.

It would be ungrateful to offer a work of the present character without a word in appreciation of the great Laboratory where, under the generous guidance of the author's friend Professor E. B. Poulton, so very much has been done to advance our knowledge of insect habits and life-histories, and where, either by him or under his direction, much of the subject-matter of this book has been evolved. Professor Poulton's own works are numerous and widely known to all entomologists, and the Hope Department at Oxford numbers amongst its contributors and workers many who have found a life-interest in the Science of Insects. Not a few of these owe their happy possession to the inspiring encouragement of its Director, whose advice and assistance are ever at their disposal.

It would scarcely be possible here to acknowledge by name the many friends who have directly or indirectly assisted me, if not in the actual compilation of this little work, at least in many of my researches. It is one of the

charms of scientific investigation that those engaged in it are ever ready to help each other, and I would express my gratitude to my fellow workers, both in the Hope Department and elsewhere, for their unfailing good-fellowship and ready response.

The majority of the illustrations are original, but I have to thank the Council of the Entomological Society of London for their kind permission to reproduce some of my own drawings, and also those of other authors, which have already appeared in their publications. My thanks are also due to Mr. W. H. Tams for the figure of the wings of the 'Whistling Moth', and to Mr. E. E. Green and Mr. F. W. Frohawk for Figs. 20 and 50 respectively, which are copied from their drawings; and I am indebted to the excellent readers of the Oxford University Press for many valuable suggestions. Prof. Poulton and Comm. J. J. Walker have very kindly assisted me by reading the proofs.

The problem of reference to exotic insects which have no English names has been a difficulty. To the unscientific reader the Latin names used by men of science are uninteresting and, it may be, even meaningless. Every known creature has two Latin names, the first that of the Genus to which it belongs, and the second its own distinguishing name, the name of the Species. In such cases I have used the latter in the text as the only title available, and for the benefit of the scientific reader I have inserted the full name in the index.

In dealing with Natural History subjects the word

species is frequently used, and it seems desirable here to explain its meaning. Perhaps few words are more loosely and incorrectly used in ordinary writing and conversation. How often one hears the statement that two animals are of the same species, when the speaker merely means that there is some general natural relationship between them. Thus a Lion and a Tiger will be quoted as of the same species. The Lion and the Tiger are both cats and belong to the same Genus, but they do not mate together and so are different species. It should be understood then, that *species* is one of the most limited of the terms used in reference to animals and plants. Any two kinds of creature which are sufficiently distinct to preclude normal mating are of different species. Thus our two common butterflies, the Large and the Small Cabbage White, are not of the same species. There is only one term having a more limited meaning, and that is *variety*. Thus if we found a Fritillary Butterfly with more or less than the usual number of spots, it might be described as a *variety*. Apart from such exceptions, species is therefore the smallest difference we make between different kinds of living things, and has no wider significance. Owing to certain rare exceptions to what may be called the mating test, a perfect scientific definition of the word 'species' is difficult to formulate, but for general purposes the rule offers a sufficient guide to the proper use of the term.

I

THE LIFE-HISTORY OF A BUTTERFLY

THERE is unfortunately no popular synonym in our language which can be used both for butterflies and moths. Scientific men, when including all the insects of this group, refer to them as the Lepidoptera, a word meaning scale-winged, from the fact that the wings are more or less covered with tiny scales, forming the 'dust' which comes off so easily on our fingers if we handle them. The French word *papillon*, though more usually applied to butterflies in particular, may also include moths, and the German *Schmetterling* and *Falter* are applied to either. Since the present work does not treat of butterflies alone we must allow ourselves the latitude of making our title include moths as well. One of the questions most commonly put to the collector by his friends is, 'What is the difference between a butterfly and a moth?' The reply is not one which can be adequately conveyed in a few words. So far as our British species are concerned they can be distinguished by the antennae, which in butterflies end in a club or knob, whilst in moths antennae may be pointed, thread-like, feathered, or even thicker at the outer end than near the head, but never suddenly clubbed. These distinguishing features do not apply universally and there are other and more important differences, but as this is not a work on classification we need not dwell on them.

Nearly every one knows this much of the life-history of a butterfly—that it lays eggs, and that each egg hatches, not into a butterfly, but into something as unlike that airy creature as can well be imagined. Out of the egg comes a caterpillar or larva, though not every one has watched the process of hatching. The egg itself is often an object of the greatest beauty, as we shall discover later. Just before hatching the little caterpillar can often be seen through the partly transparent shell. It lies curled up very closely, and once it has escaped it would

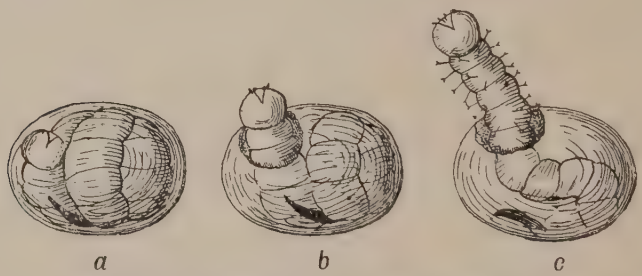

FIG. 1. Egg of the Eyed Hawk moth hatching : *a*, egg containing young larva ; *b*, shell breaking ; *c*, young larva emerging.

be a difficult matter again to pack it into the shell. When the proper time comes, the tiny jaws can be seen gnawing away at the inside, but since this is very smooth and there is nothing to bite upon, progress is slow. But at last patience is rewarded and the shell is worn so thin that a crack is made and the little creature can obtain a real bite at the broken edge. Very quickly now it gnaws a hole large enough for its head to emerge and creeps out without further hindrance.

The next proceeding is often rather surprising. It turns round and eats the remainder of the egg-shell.

This is not an invariable habit, although a very common one. Sometimes, indeed, the young caterpillar cannot be induced to touch any other food till it has had its *hors d'œuvre* of egg-shell, and if deprived of this it will die of starvation though surrounded by the leaves of its proper food plant.

At Fig. 1, *a*, *b*, *c*, I have sketched the emergence of the caterpillar of our 'Eyed Hawk' moth. In its earliest stage it is covered with small forked hairs, and the red horn on the hinder end is very long in proportion to the rest of the body. This larva eats very little of its egg-shell, merely nibbling the broken edge.

There is a popular impression that lettuce or cabbage is beloved of all caterpillars, but though some species will eat a great variety of plants, the majority can exist only on their own particular food and will die if this be not available.

Our caterpillar now begins the one great business of caterpillar life, eating. Its digestion seems almost continuous, and in its little body there is gradually stored up that great reserve of material which will provide first for the chrysalis or pupal stage when it can eat nothing at all, and ultimately build up the beautiful wings and body of its perfect state.

Its growth in weight and size is very rapid, though curiously enough the only part of it which does not grow proportionately is the skin, so that having reached a certain stage of expansion the skin is of necessity thrown off and a new and larger one appears beneath. This process is repeated several times during its life, and finally it becomes fully grown and casts its skin for the last time. Then, however, instead of a caterpillar

emerging, an entirely new form appears, the chrysalis or pupa. In this stage it takes no food. It cannot walk about, though sometimes a slight wriggling movement of the jointed body is possible. It remains thus for a period which may vary in different species from a fortnight or so to several years. Some forms will safely survive the coldest winter; others will remain for two years or more and yet bring to birth the winged creature which has been forming within. Sooner then, or later, if no accident has befallen it, the moth or butterfly breaks open the pupal case. First the legs and antennae, then the wings, and finally the body is drawn out, and a sorry-looking little object creeps up and seizes with its tiny claws some suitable support. It is soft and flabby, and the wings look, but not for long, like small crumpled bags. It cannot truly be said that the wings grow. That which really happens will be described later, but what appears to happen is that they expand rapidly somewhat after the manner of the little Japanese toys which seem to be crumpled shavings and swell into flower-like forms when thrown into warm water. In some species the process may take a few hours, but on the other hand I have seen our little 'Purple Hair-streak' fully developed in about five minutes after it has emerged. Without any lessons in aerial navigation our butterfly floats off into the air, perfect in all its exquisite form and colour, and ready to pursue its sole objects in life, food and a mate.

It must not be supposed that every caterpillar which hatches, thus attains to perfection. From the egg onwards relentless and watchful enemies are ever on the look-out for its destruction. Indeed, if it were not so the

world would soon be buried in butterflies and moths. Small birds and other creatures, including earwigs, eat the eggs. The caterpillars and pupae are eaten in millions by birds and other insectivorous animals, whilst the butterflies and moths are themselves the food of many enemies. Measured over a long series of years the average surviving offspring of two moths is no more than two; if it were more the increase would result in race suicide through starvation, if less the species would gradually become extinct.

Probably the most successful of all the controlling factors are certain other insects which live entirely on caterpillars. They are the Ichneumon flies and some other flies not related to them. These flies lay their eggs in or upon the caterpillars, and from these eggs there hatch tiny grubs which grow and develop in or upon their hosts, and, after finally destroying them, pass through a pupal stage of their own and emerge as ichneumons or flies like their parents. These parasitic insects cannot exist in any other way, and the female ichneumon searches out with unfailing precision the particular species of caterpillar that she affects. Some caterpillars are affected by several different parasites, and some parasites attack more than one species of caterpillar. Fig. 2, *a*, shows a much enlarged view of the parasite which attacks the cabbage white butterfly. Fig. 2, *b*, is the mass of cocoons of the parasite clustered round the skin of their victim. They are often destroyed by gardeners under the impression that they are the caterpillars' eggs!

How have these delicate and vulnerable caterpillars continued to defeat, at least partially, their innumerable foes and survive through past ages? There are many

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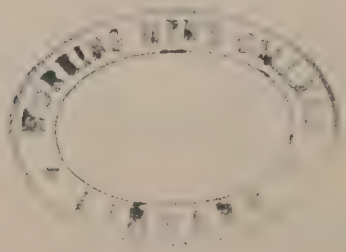
moths and butterflies; why do we not see them more often? If those of us who are not collectors look into our friends' cabinets we are sure to notice many forms which we have rarely or never observed before, but which our friends tell us are common enough. Why do we so seldom see them? What special defences has an

Fig. 2. *a*, Parasite of the Large Cabbage butterfly much magnified; *b*, cocoons of the parasite clustered on remains of larva.

apparently defenceless caterpillar? How does a moth find its mate in the dark? What is the meaning of the patterns and colours of the caterpillars and their butterflies? Have they senses similar to our own? The answers to these and many other questions form the theme of the present work. They will provide, it is hoped, some excuse for those who study such 'trivial' subjects.



II

THE FIRST BUTTERFLIES

In the study of Geology we are frequently able to say with certainty that certain forms of life existed at an earlier or later epoch, but when we attempt to assign actual dates to the periods represented in the tables of the stones we have little to rely on save speculation.

There is a formation known to geologists as the Devonian or Old Red Sandstone Epoch. If we set out the recognized geological periods in a column, and give each a space in proportion to its known thickness, the Devonian period comes about half-way between the present time and that age associated with rocks which show such evident signs of intense heat and pressure that we cannot hope to find therein any remains of past forms of life. Except for the Silurian cockroaches, which are found at an even earlier level, it is in these Devonian rocks that we discover the first remains of insects. Who does not know the May Fly, beloved of the fisherman? a delicate creature which though it lives for long in the water as a swimming larva, yet needs its lacework pinions and its flowing plumes for a honeymoon so brief, that in its final stage Nature has not even given it a throat, since it will die before ever it can feel an appetite. Our May Flies are small, but the Devonian ancestor was a giant of the May Flies, some five inches across the wings. It is not

to be supposed just because this is one of the first insects of which we have a record, that May Flies were suddenly created at that time. Its presence is merely evidence that in the long panorama of evolution insects had then reached a highly developed state; so much so that from being creatures of the land they had developed the power of living in water.

Although from this time onwards insects occur in the fossil records, we look in vain for butterflies, and it is not until we reach what is known as the Tertiary Period that we find evidence of the first fossil butterfly, and that is but the imprint of the wing. Fossil butterflies are of the greatest rarity, and perhaps not twenty specimens are known, but from these we learn that they were well established before our own species ever trod the earth. If we make a scale, taking one foot (in the depth of the geological strata) to represent a thousand years, then the original of our earliest fossil butterfly, even then attained to its present form, fluttered in the sun of three million years ago. But such calculations are but guess-work, and the most we can say is that they probably err in the direction of a too short allowance of time. When Man developed sufficiently to amuse himself by drawing pictures, he confined his subjects mainly to the edible objects of the chase, and since butterflies did not afford him food, he did not record their forms. I have heard of no primaeval drawings of insects. For the first recorded picture of a butterfly we must come down to a mere three thousand five hundred years ago, the supposed date of the Theban fresco in the British Museum, on which are depicted certain butterflies. The outlines are blurred and their identity is doubtful, but

they certainly give the impression of being rough representations of an orange and black species which survives in Egypt to this day.

Let us leave the remote past with its fascinating but misty speculations. Doubtless the insects of those days were interesting enough had there been any one to observe them. Their records are for ever lost, but their descendants afford greater cause for wonder, since their very survival presupposes a more complete history.

III

EGGS

THE expression 'egg-shaped' is familiar enough and conveys a well understood meaning, but had the original maker of the phrase seen a butterfly's egg, he could scarcely have been congratulated on his definition. A famous chef asserted that eggs were the basis of all culinary art; we might almost maintain that butterflies' eggs contained the germ of all decorative art. It is unfortunate for those who think that all creation exists for the enjoyment of Man, that Nature should have lavished much of her most exquisite decorative art on objects so small that our unaided eyes could never have observed them. The wonderful tracery of the microscopic diatom, the geometrical beauty of snow crystals, the sculpture of the radiolarian shells, are known only to the microscopic eye, and neither man nor any other creature has been given eyes that can appreciate them unaided. Probably the butterfly never sees its own eggs, and would have little regard for them if it did. Other creatures which do see them perceive merely with the fleshly eyes of hunger, and can hardly be supposed to possess the rudiments of aesthetic appreciation. It is perhaps unnecessary to endeavour to find a special reason for the beauty of some butterfly's eggs, since the answer lies not in the eggs but in ourselves. The egg must have

a shape of some kind, and if that shape happens to correspond with our idea of beauty we marvel at it, forgetting the many shapes which do not specially appeal to our eye.

Fig. 3 shows the egg of our little Orange-Tip butterfly. Its near relations, the Green-Veined and Cabbage Whites, produce eggs of very similar form, and nothing is easier than to watch the Large White cementing its eggs to our cabbage leaves, and then to remove and

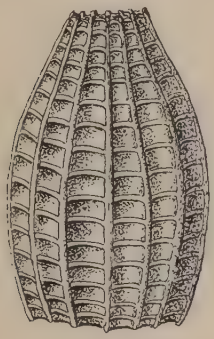


Fig. 3. Egg of Orange-Tip butterfly (magnified).

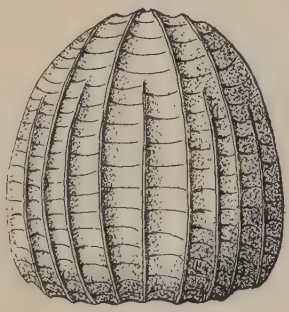


Fig. 4. Egg of Fritillary butterfly (magnified).

examine them with a pocket lens. The beauty of the eggs may not compensate us for the ultimate damage to our cabbages, but as each egg when removed will be rendered harmless, we can at least afford to admire it without prejudice. Fig. 4 represents the egg of one of our large Fritillaries and is typical of the structure found in that genus. Fig. 5 is one of the most beautiful we have, that of our White Admiral. No mere black-and-white drawing can give an adequate idea of the beautiful little silvery-green casket which may one day

produce the most graceful fairy aeroplane amongst our butterflies. Fig. 6 is the egg of the Holly Blue. In early spring you may see this, the first of our blues, hovering round a holly bush. Rapidly it will settle on a flower bud, and if you would find the egg it has laid so quickly you must mark the place well, for so perfectly does it blend with its surroundings that some practice is required to discover it. There it lies, probably on one

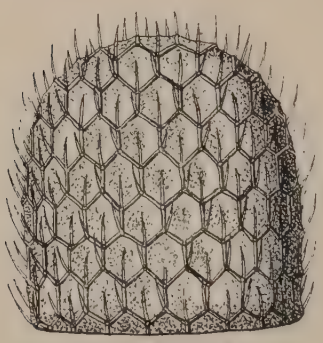


Fig. 5. Egg of White Admiral butterfly (magnified).

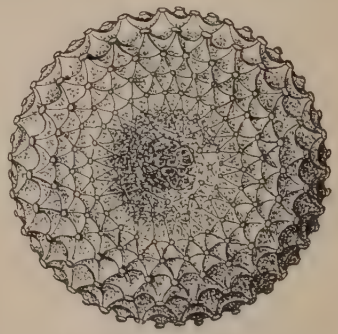


Fig. 6. Egg of Holly Blue butterfly (magnified).

of the short flower stems, looking like a minute opal, and a small lens will reveal the elaborate sculpture which I have endeavoured, however feebly, to reproduce. This butterfly is double brooded, and only those hatched in spring lay their eggs on holly. From these eggs butterflies are produced in summer, and these lay their eggs on ivy. Pupae of these do not hatch till the following spring, and these again select holly. Fig. 7 shows the egg of the Red Underwing moth, a large insect with mottled grey fore-wings and scarlet hind-wings banded with black. The caterpillars feed on poplar and willow,

but are very difficult to find since they lie in crevices of the bark by day and match their surroundings very perfectly. The egg is pale brown with dark irregular markings, and tiny delicate white frills like elevated lines of longitude on a globe.

Fig. 8 illustrates the egg of the August Thorn moth. The eggs are green and very shiny, in shape like oval barrels. They are laid in groups formed of regular

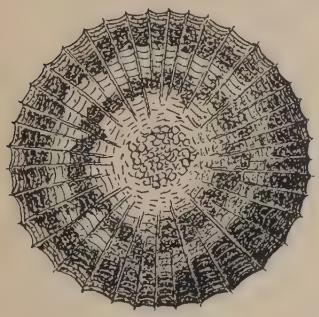


Fig. 7. Egg of Red Underwing moth (magnified).

Fig. 8. Egg of August Thorn moth (magnified).

rows, each egg attached to its support by the rounded end. The top is flat, encircled by a thickened projecting rim of a yellowish colour.

The eggs of exotic butterflies doubtless present equally beautiful patterns and forms, but as yet they are but little known. I have said that normally caterpillars must have as food the leaves of a particular plant. The mother butterfly seems never at fault in her choice. She may be no general botanist, but she is certainly a specialist, and since she selects her own plant with unfailing accuracy, we must suppose that her keen

power of scent is her principal, perhaps only guide.[1] Butterflies' eggs are often laid singly. Moths' eggs are more frequently found in batches, sometimes arranged with great regularity. The Lackey moth places her eggs in a ring round a twig. Some moths are not careful to select their food-plant, some do not select a plant at all. The common Yellow Underwing frequently lays her eggs on the strings of a tarred netting round a tennis court. It was some time before I discovered the maker of the little seed pearls that so frequently appeared in this position, and curiously enough the actual discovery was accompanied by one of those tragedies but for which insects would soon destroy all vegetation. Searching one evening with a lamp I found the moth industriously fixing her eggs to the netting, but she was not alone. Behind her was a hungry earwig, and almost as fast as the moth produced the eggs they were broken and devoured. Next morning a débris of egg shells told a tale of frustrated maternity. Not one remained whole. The caterpillars of this moth are general feeders, and thus no great care is necessary on the part of the parent in the choice of her 'nest'. Suitable food is abundant and likely to be near at hand; nevertheless I was anxious to see how the young caterpillars would leave their inedible birthplace and find with the least delay their proper food. Careful searching revealed a brood just hatched. As in so many other species the

[1] Butterflies when laying their eggs have been seen to move their feet over the leaves with a rubbing motion, and there are certain bristles on the feet of female butterflies and moths which are peculiar to that sex. It may be that these bristles are the outward part of a special organ of touch or scent which assists them in their choice of food-plant. The matter is still being investigated.

egg shells formed the first meal, nothing remaining but the small area attached to the netting. What would they do next? The solution was very simple. Each produced a fine thread of silk and, reversing the alleged Indian conjuring trick, let itself gently down to the grass below.

Butterflies' eggs may remain for days, weeks, or a whole winter, but eventually the caterpillar is formed within, and the process of biting its way out begins. It emerges to face the most dangerous period of its existence.

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IV

CATERPILLARS

To attempt a discussion of the minute structure of a caterpillar would probably defeat the purpose of this book, which is that it should be read; but at the risk of proving dull, some account must be given of the caterpillar's form, in order that later and more interesting matters may be more easily explained. The caterpillar may be simply described as a worm-like creature, in which the most casual observation can distinguish at least a head and body. There is a little poem which recounts the discomfiture of a bishop who was asked how many legs a caterpillar had; the climax of the tale is the routing of the learned cleric by the observant scholar, who, having recently counted them, announced that it had six. Alas, the learned scholar was as ignorant as his bishop, for if legs are the organs used for walking, then caterpillars are more plentifully endowed than he supposed. At the fore-part of the body the creature has six legs, which are the true legs corresponding with those of the butterfly in its mature state, and in addition the larvae of butterflies and of very many moths have ten temporary legs provided with powerful muscles and crescents of tiny hooks which enable them to hold firmly to the plant on which they feed.

In animals like ourselves the skeleton is inside the body and our muscles are attached to the outside of the skeleton.

In insects the reverse is true. The hard parts are outside, and the muscles are attached to the inside of the skeleton, mechanically, a very superior arrangement. Now a caterpillar's whole business in life is eating, and therefore the head is very hard so as to form a sound attachment for the powerful muscles which move the jaws. The jaws of an insect, if and when it has any, always

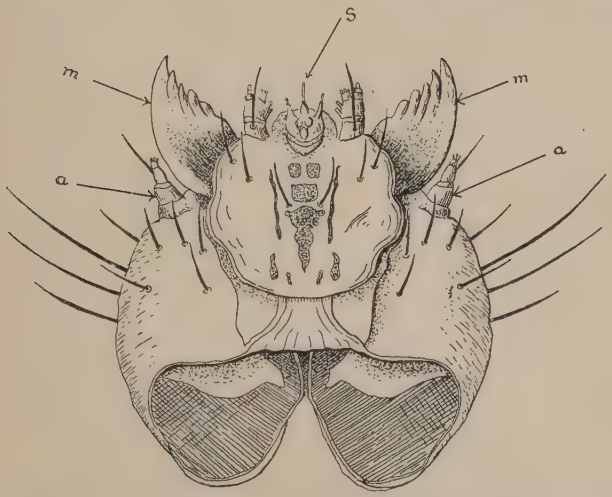

Fig. 9. Head of Goat moth caterpillar seen from beneath (magnified). *a*, antennae ; *m*, jaws ; *s*, silk tube (adapted from Lyonnet).

move sideways, instead of vertically as in vertebrate animals. There are other organs on the head which assist in the manipulation of the food, two very small antennae—probably organs of touch and scent, a tiny tube from which issues its silk, and on each side six minute and very rudimentary eyes which can probably do little more than distinguish light from darkness. These eyes contain an almost spherical lens, beneath which is a

group of sensitive nerve-endings. All the six eyes are on branches of a single main nerve. Fig. 9 shows the head of a caterpillar greatly enlarged. Like all insects, it breathes through little openings in its body which lead to a network of minute branching 'tracheal' tubes carrying the air to every part of its anatomy. It has a rudimentary heart consisting of a long pulsating tube running down the back and open at the ends, which serves to keep the blood in motion. There are no veins and arteries, the blood fills all the spaces of the interior. The very simple brain consists of two little masses of nerve-tissue from which two delicate nerve-cords pass through the whole length of the body, giving off many finer branches. The stomach is large and very active; it has various accessory glands, and there are silk glands, which may be small, or very highly developed, as in those species which make large cocoons.

Such, together with a great number of muscles, is the equipment of this simple creature, but very often there are remarkable additions and special structures which, as we shall see, form the caterpillar's most interesting features.

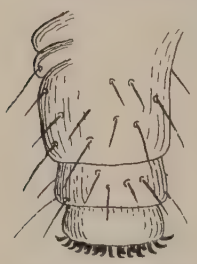

Fig. 10. One of the hind legs of a caterpillar showing the hooks on sole of foot (magnified).

Let us return once more to the legs of our caterpillar; the first six are jointed tapering structures ending in a claw. They are used mainly for holding the leaf whilst it is being eaten, though they are also of some assistance in walking. The remaining legs are of more elaborate structure and repay some examination. Fig. 10 shows a side-view of one of these. Certain

primitive moths, usually small, have caterpillars which are provided with a complete circle of hooks on the sole of the foot, but those of butterflies and the larger moths retain only the inner half of the ring. The action of these hooks is easier to see in nature than to describe on paper. They all curve outwards from the centre of the 'sole', which can be expanded and contracted. When expanded the hooks of opposite feet move towards each other, and so the stem, or whatever the caterpillar is on, is firmly gripped. When the 'sole' contracts the hooks of opposite feet move away from each other so that the grip relaxes. When the creature is walking, this opening and closing takes place so to speak in waves, two feet opening and moving on, then the next two, the movement being taken up by each pair in succession, so that, though moving, the caterpillar always has a firm grip of its support.

In the well-known 'looper' caterpillars there are only two pairs of temporary legs, and the creatures move by seizing some object with the front legs and then drawing up the rest of the body till the temporary legs come close to the head, the body projecting upwards in a loop; having secured a firm grip with the temporary legs the front portion of the caterpillar again moves forward. The creatures thus appear to be 'measuring', and the group to which they belong is known as the Geometers, or earth measurers. One of these caterpillars is shown at Fig. 11.

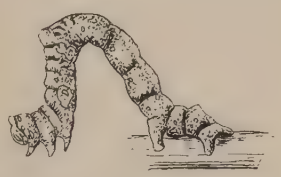

Fig. 11. A Geometer caterpillar in walking attitude.

The casual observer is familiar with very few cater-

pillars because many are so perfectly hidden that even for an expert collector they are difficult to find. Some are literally hidden, in that they conceal themselves by day and come out to feed only at night. Others are concealed very effectively though fully exposed to view, and I have endeavoured to show to interested friends caterpillars which they could not see though they were near enough to be touched. Others again are very conspicuous. Often they are brightly coloured and lie fully exposed in strong daylight, as if bent on advertising their presence to all who may pass that way. Now a caterpillar is easily killed. It is a delicate organism, usually with a soft skin in which the blood is under slight pressure. Let it suffer the least scratch, or the peck of a bird, and even if not eaten it will probably bleed to death. Why should it be so seemingly careless of its life and risk destruction when it might so easily hide?

We owe the original explanation of this phenomenon to the late Alfred Russel Wallace, to whom Darwin referred the question. His suggestion was that such conspicuous creatures were probably nauseous to their enemies. If this were so it would be a great advantage to advertise themselves as much as possible so that birds and other creatures would the more quickly learn to recognize them as unpalatable. This is known as the Theory of Warning Colours. It is now much more than a mere theory since innumerable experiments all over the world have shown that not merely caterpillars but many other brightly coloured creatures are in fact protected by their nauseous properties.

If the reader cares to try an experiment for himself, let him take a few of the conspicuous caterpillars of the

Magpie moth, only too often to be found on our currant bushes, give them to his chickens, and watch their behaviour; then as a contrast let him try the chickens with almost any of the night-feeding caterpillars. It is curious that although birds, unless almost starving, refuse the larvae of the Magpie moth with every sign of disgust, they are not specially unpleasant to the human taste, for, extraordinary as it may seem, there are venturesome spirits who have tried them, and affirm that they have but little flavour, pleasant or otherwise. It may here be remarked in parenthesis, that caterpillars are by no means invariably rejected as an article of human diet, certain kinds being much esteemed by some African and Australian tribes, and should the reader ever have occasion to accept native hospitality, he will do well to examine with care the solid objects to be found in the soup.

The nauseous properties of some caterpillars are to be traced directly to the food they are eating, as for example, in a certain species experimented on by the writer. The larva which was the subject of the experiment is so like a twig that it is extremely difficult to detect. This stick-like appearance, often found in caterpillars, being usually combined with edibility, it was surprising to find that lizards, after a trial, refused them with manifest signs of disgust. These caterpillars were feeding on ivy; they will also eat apple leaves, and it was found that after a day or two's feeding on apple the lizards ate them greedily. In this case there is a simple and direct connexion with the food, but a much more interesting example is that of a larva of very retiring habits, rarely seen, and not feeding on an acrid plant, but found by Professor Poulton to be very distasteful to insectivorous

animals. Here as often, the unpleasant properties are elaborated by the vital processes of the creature itself, and the example shows how a nauseous flavour may be accidentally acquired, without any corresponding development of conspicuous or warning colours.

The defences of caterpillars are very varied, unpleasant taste being only one of the devices by which they survive. Hairy caterpillars are familiar to most dwellers in the country, and even those who rarely leave the towns may have seen the caterpillar of the Buff Ermine moth, which often feeds on elder bushes. It is covered with pale brown fur and is remarkable for the rapidity with which it can run, its hurried gait being very unlike the solemn crawl of most other species. Birds and lizards do not as a rule like hairy caterpillars, and it seems easy to account for this, by the mere mechanical unpleasantness of the hairs. It would however seem that the thick coat affords protection in another way. Most of these furry kinds roll themselves up when alarmed and drop to the ground. Now a fall of this kind is an adventure not lightly to be undertaken by so soft and delicate a creature, to which a very slight injury may prove fatal. But our 'Woolly Bears' and Ermine moth caterpillars can risk a fall on to even a hard surface since the shock of their landing is effectually modified by the stiff springy hairs. This explanation was originally offered by the late Professor Meldola. A further suggestion is made on the subject by Professor Poulton, who points out that the thick tufts of hair on some larvae, such as the beautiful 'Hop Dog', are so compact as to suggest actual projections of the body, and markedly so when the creature rolls itself up tightly. An enemy will then be tempted to seize one

of the tufts, but will only secure a mouthful of very irritating hairs. On making the experiment with a lizard this actually took place, the larva escaping and the lizard being greatly inconvenienced by the hairs. Strictly speaking, nearly all caterpillars are hairy, though

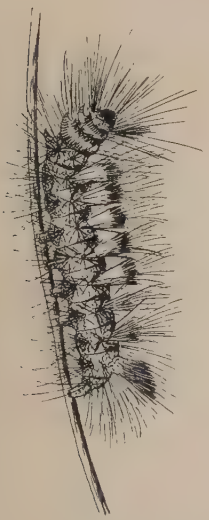

Fig. 12. Caterpillar of a Tussock moth.

Fig. 13. Head of the Vapourer moth caterpillar showing plume hairs and bristles (magnified).

(The projections from which the plume hairs arise are not the eyes, which cannot be seen from this point of view.)

in many the growth is almost microscopic, varying upwards from this through coats of fine down to the thick fur of the Tiger moth larva.

In the process of evolution hairs of many forms have been produced, and their arrangement is often of great beauty, as in our Vapourer and Tussock moths. One of the latter is shown at Fig. 12, and Fig. 13 is an enlarged view of the head of a Vapourer moth larva with its

delicate plume-like hairs. Amongst their modifications some of the most interesting are the so-called 'urticating' hairs or 'spicules' which grow on the bodies of many larvae of moths, and, as recently discovered, of some butterflies.

They take the form of very minute barbed darts, and are produced, not to provide a clothing for the wearer, but in order that they may fall off with the greatest possible facility and enter the skin of unwary intruders. Here they cause intense irritation, which sometimes gives rise to conditions resembling acute eczema. The degree of susceptibility to their action varies greatly in different individuals, as also does the virulence of the spicules of different species of caterpillar. One of the worst of our European species is the Pine Processionary caterpillar, whose story has been told at length in the fascinating works of the late Henri Fabre. That Fabre was not invariably correct in his conclusions is now abundantly proved, though his errors can detract neither from the beauty and simplicity of his writings, nor from the untiring patience and ingenuity of his observations.

The Processionary caterpillar is a social being, with rather unpleasant properties, and it doubtless derives additional protection from its 'massed formation'. The eggs are laid in batches of about three hundred or so on Pine Trees, and covered with the large scales which form the great tuft at the end of the moth's body. The young caterpillars make a nest of silk in which they live, eating the enclosed pine needles. When these are consumed they move on and enclose fresh ones. They pass the winter in a similar though stronger and thicker nest, in which they do not eat the pine needles. Were

they to do so, that branch would wither and probably break off. This winter nest is constructed gradually, the larvae feeding by day outside it, and adding layer on layer of silk. The construction of the nest is an unconscious and blind instinct, as is shown by Fabre's experiment of cutting a hole in it. This hole the larvae failed to close except in so far as chance threads crossed it. The name 'processionary' is applied to the caterpillar because on their expeditions abroad they walk in a regular procession, head to tail. In doing so they spin fine threads of silk, to which each adds a quota, ultimately forming a silk ribbon, a highway so to speak, leading back to the nest. Even should they separate when feeding, each continues to lay a thread by means of which it will find its way back again. Fabre describes a procession of these caterpillars numbering some three hundred, and measuring twelve to thirteen yards in length. If placed on a circular ledge such as the top of a flower-pot, the caterpillars will walk round and round it for days without perceiving the presence of their food plant but a few inches away. In a brood of these larvae which I kept in a glass cylinder resting on a flat tray filled with sand, I observed a curious habit which appears not to have been recorded. My caterpillars frequently marched round the cylinder for long periods at a time, but at intervals, as though by some simultaneous impulse, they would all bury themselves in the sand, and this so completely that they entirely disappeared. After a while they disinterred themselves and again started on their march.

To return to the urticating spicules. On the back of the caterpillar are transverse slits, which, on being

touched, open widely and protrude what looks like a velvet pad, but the velvet is not of a kind from which one would care to make a garment. It consists of barbed spines immeasurably sharper than any needle of human construction, and so small that a thousand or so look like a speck of dust. If these find their way into the skin they speedily set up an irritant rash, worse than hundreds of nettle stings, and far more lasting in its effect. There can be little doubt that this property affords considerable protection to the larvae, and one unhappy experience is probably quite sufficient to cause birds and other creatures to look elsewhere for food. The cause of the irritation is still rather doubtful. Fabre experimented painfully and laboriously, applying them to his own person in a variety of ways. He convinced himself that they do not in fact enter the skin. He soaked the skins of caterpillars in ether, and found that after this treatment they no longer caused the irritation although the barbed spicules were present. The ether solution on the other hand produced after some hours a very serious blistering, from which he concluded that there is a poison in or upon the spicules, and the more rapid effect produced by these in their unwashed state is due to the spicules assisting their action mechanically. But surely to do so they must enter the skin or at least scratch it, which seems contrary to his previous conclusion. Fabre pursued his investigations with the result that he found that an ether extract of the excretions of the caterpillars produced the like irritation, and he concludes that the spicules of the caterpillars are in fact poisoned by contact with the excretory products in the shelters in which they live.

This may be true of the Processionary caterpillar, but does not account for the equally irritating properties of the spicules of our common Gold-tail moth. This caterpillar does not live in shelters and its spicules cannot in any way become contaminated by the excretions, nevertheless the spicules are (to the writer) quite as virulent as those of the 'Processionary'. Moreover, before reading

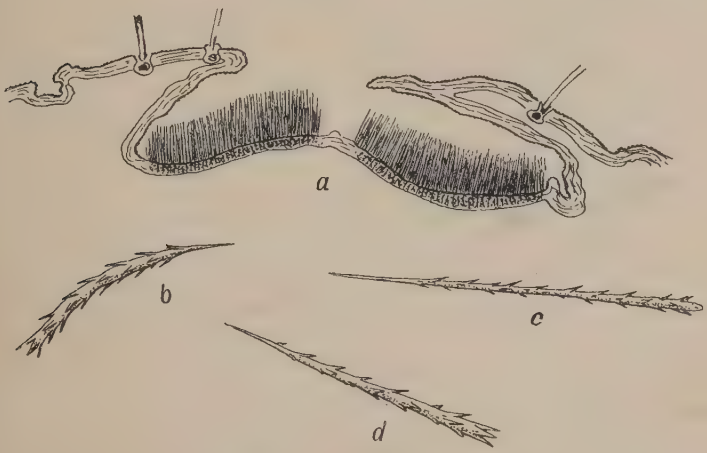

Fig. 14. *a*, section through skin of the Pine Processionary caterpillar showing eversible pocket containing irritating spicules; *b*, one of the spicules from the larva of an African butterfly (*Teratoneura isabellae*); *c*, ditto, from that of the Pine Processionary; *d*, ditto, from that of the Gold-tail moth (all magnified).

Fabre's work, I had tried the experiment of washing the spicules with solvents of various kinds, and though I did not test the urticating powers of the solution so prepared, I found the spicules when dried just as irritant as before. Further experiment is undoubtedly required to solve the mystery of the poison, if poison it be. At Fig. 14, *a*,

is shown a section through the skin of the back of a Processionary caterpillar. It shows the pocket with the masses of spicules growing therein. Fig. 14, *b*, is a spicule from the larva of a small African butterfly (*Teratoneura isabellae*), the only butterfly larva yet known to produce them. Fig. 14, *c*, is a spicule of the 'Pine Processionary', and Fig. 14, *d*, the one from the larva of the 'Gold-tail moth'.

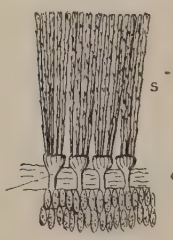

Fig. 15. Section of skin of the larva of the Gold-tail moth, showing the spicules arising from the rosette-like bodies, communicating with cells beneath the skin. *s*, the clusters of spicules; *c*, the skin; T, the connecting tubes (all magnified).

Interesting as is the Processionary caterpillar, the Gold-tail moth exhibits a train of instinct even more remarkable. Who in the country has not seen the beautiful dark furry caterpillar with its scarlet spots and tiny white plumes, carelessly exhibiting its beauties on the thorn leaves of the hedgerows? To the hungry bird the red light of danger is probably familiar enough, but such signals were not developed to forestall and lessen human interference. Many an incautious young collector has eagerly seized the beautiful creature, and paid for the enthusiasm of ignorance with a mysterious attack of nettle-rash? The seat of the trouble is the little dark velvet pads on the back of the caterpillar. Tens of thousands of the vicious darts lie point downwards in these pads like arrows in a quiver. Fig. 15 shows a section through a small piece of the skin of the caterpillar.[1] *c* is the

[1] In the microscopic investigation of small objects the method of cutting sections is very widely adopted. A homely illustration may serve to make the matter plain to those who are unacquainted with the

actual skin, and immediately underneath it are found masses of tiny cells which supply the material from which the spicules are formed. They communicate through fine tubes, T, with rosette-shaped bodies from which the spicules themselves, *s*, arise in bundles. Each spicule is attached only by its delicate point and so falls off at a touch. So far our Gold-tail caterpillar differs but little from others similarly armed. A more remarkable feature is the fact, long ago observed, that the female moth also possesses the power of producing the rash. To discover the reason for this it was first necessary to decide whether the moth also possessed the poison darts, and microscopic examination at once showed that they were present in the thick tuft of gold 'fur' which is the only relief to her otherwise silvery white costume. The question arose, did they grow on the moth as they do on the caterpillar? To solve this problem it was necessary to obtain a moth which could never by any chance have come into contact with the old caterpillar skin, or the cocoon in which it lay. This was a matter

process. Suppose we wish to discover the exact shape and position of all the substances in a cake; if we were to cut it into a great number of thin slices, and lay them all in a row in their proper order, we could, from these sections, discover the shape, number, and position of every currant, raisin, or other ingredient, and by making a careful comparison of all the slices, the shape of the cake itself. In the same way, by cutting up an insect, or portions of it, into microscopically thin sections, we can discover the structure of the tissues, and the shape and position of the parts. The methods used are often complicated, and require considerable skill. Different kinds of tissue are differently susceptible to dyes, and this is of great assistance, since it is possible to impart to muscles, nerves, glands, &c., different shades in the same section, in such a way as readily to distinguish them. By means of ingenious instruments such sections can be cut as thin as the twelve-thousand-five-hundredth part of an inch or even less.

of no great difficulty. The chrysalis was removed from its cocoon, and the moth which hatched out from it examined. No spicules could be observed. Those which the moth usually possesses are then merely the old ones which remained in the cocoon when the caterpillar had shed its skin for the last time. But how do they now come to be entangled in the gold 'tail' of the moth? It may be thought that since the moth must first emerge from the chrysalis before it can make its way out of the cocoon, and since the latter contains great numbers of the spicules, their presence on the moth is more or less inevitable. This, however, is not so. The head of the chrysalis is very near the end of the cocoon. The moth has only to break through the small layer of silk immediately in front of it; having done so, it can creep out without any part of its body touching the silk at all except just at the orifice. Moreover, the spicules are never present on the male moth. The matter needed careful observation. Fortunately the silk of the cocoon is very thin, and the proceedings of the moth when making its way out can be observed through the silken envelope. First comes the breaking of the chrysalis. Out come legs, head, and antennae, and then follows the struggle to tear through the silk. This is soon over and the moth thrusts itself partly through the opening. But now the effort to escape is suspended. There is an important operation to be performed before complete freedom is attained. Drawing up her body free from the chrysalis skin, she thrusts it backwards again, pushing the skin aside. The golden tuft of the 'tail' opens and closes, while the movements of the body cause it to sweep round and round the inside of the cocoon. The

movement is comically reminiscent of an elephant's trunk making a general collection of fragments too small to be transferred singly to its mouth. Only after thus carefully sweeping its chamber does the moth resume its efforts to emerge. Once clear of the cocoon it creeps rapidly to some convenient point from which it can hang itself up to dry. The microscope discloses a further interesting fact. The golden hairs of which her tuft is composed are not altogether smooth. Each hair where it is nearest to her body is branched and spined, and when highly magnified looks like a bramble stem (see Fig. 16). Thus the irritating spicules are entangled and held in what is at present the base of the tuft. There is a good reason for this. It is her habit to lay her eggs in a little heap, and when first laid they are sticky. Having completed the laying she presses down her golden tail so that it forms a shelter for the heap, and, drawing away her body, part of the tuft remains. But now the ends by which the hairs were attached to her body are uppermost, and they contain a generous charge of the irritating darts. The enemy which would consume her progeny must first eat the darts and by the time he has tasted them will probably have lost the craving for the more solid course beneath.

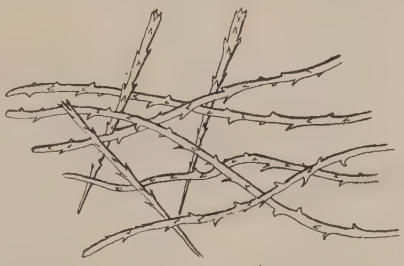

Fig. 16. Three irritating spicules entangled in the barbed portion of the hairs of the Gold-tail moth. Only the ends of these hairs are shown. On the same scale the whole hair would appear of great length.

The male moth also has a golden tuft. Does he make any use of the spicules of his larva days? Watch him come out of his cocoon. He does not wait a moment. He bores his way out and runs away to dry, and if we examine his golden tail the hairs are perfectly smooth and were never meant to hold concealed weapons.

Fig. 17. The barbed spicules of the larva of an African moth (*Parasa urda*) with the cells in the skin from which they arise (magnified).

When the female moth is at rest nothing but her silky white wings and thorax are visible, but if alarmed she raises her body and shows her golden tail. This is almost certainly a warning movement which enemies learn to recognize, and thus her hidden weapons serve for her own personal safety as well as afterwards for her eggs. The male when disturbed will do the same, but he is merely trading on his mate's reputation.

If there is still some doubt as to whether the spicules of these caterpillars are in reality poisonous, there can be none concerning the true poison spines carried by certain other moth caterpillars. Unfortunately these are rather difficult to obtain in this country in the properly preserved condition necessary for microscopic examination. They occur in many parts of the world including British Guiana, Australia, West Africa, and Ceylon. I received one specimen from West Africa, but owing to a belief that more were available, cut it into sections before making a complete portrait. It is the larva of the beautiful green Urda moth, and is surely the most

heavily armed of all caterpillars. In the first place it possesses masses of urticating spicules larger and more fiercely barbed than any others I have seen. Fig. 17 shows a magnified view of these. It is remarkable that, unlike those of other caterpillars, they grow with the sharply pointed end outwards. In addition to these there are clusters of very small, many pronged bodies which

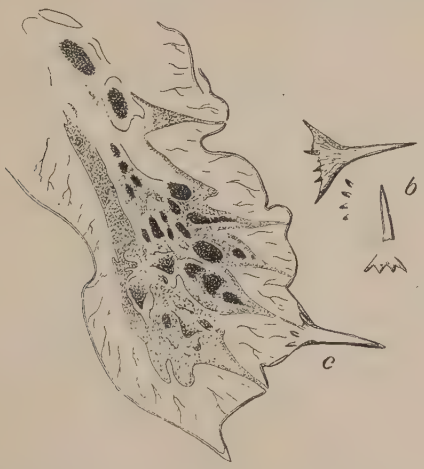

Fig. 18. Section through one of the projections on the skin of the larva of *Parasa urda*, showing the 'caltrop' formation at *c*, and others detached and broken at *b* (magnified).

grow on the skin and are easily detached. They resemble somewhat a wicked device which used to be employed to lame horses in war, known as a caltrop. It consisted of a spiked ball so arranged that when thrown down one of the spikes always stood upwards. In the caterpillar the action of these pronged bodies is doubtful, though they may well cause considerable irritation to the mouth and throat of an enemy. Fig. 18 shows a section of one

of the warty projections of the caterpillar's skin with a 'caltrop' growing at *c* and some broken-off portions at *b*.

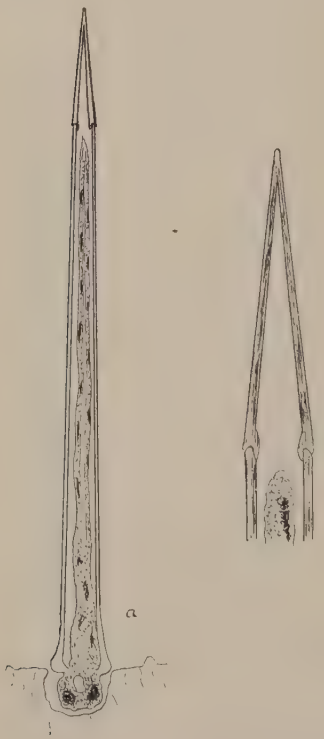

FIG. 19. *a*, one of the poison spines of the larva of the moth *Parasa urda*, with poison gland inside. *b*, end of spine still more magnified to show detachable point.

But the creature's most formidable weapons are the poison spines, clusters of which project from wart-like excrescences of its body. Their construction is almost devilish in its ingenuity. It is not that the outer surface is merely smeared with poisonous material; such an arrangement would be but a reproduction of the crude methods of the savage. Instead the more scientific principle of the hypodermic syringe is made use of. Each spine is a tube, fed by a special gland in the larval skin. Were this tube open at the end the fluid would escape when not required, but such a contingency is provided for by a stopper which is sharply pointed at its outer end, and fits the open end of the spine like a cork. Touch the caterpillar and several of these spines will certainly pierce the skin. The least movement

displaces the stopper and the poison is injected into the wound. Comm. Walker, who has seen similar caterpillars in Australia, assures me that if the finger be brought close to the living larva, it actually turns its spine batteries in the direction of the approaching enemy. Such a movement is not easy to explain, since the creature's eyes are very rudimentary and cannot be supposed to be acute enough to direct so purposeful an action, but microscopic examination shows that in the centre of each spine cluster is a long delicate bristle, presumably connected with the nervous system. The approaching enemy probably touches the bristle, which is a sensitive organ, and so reveals to the caterpillar the line of attack. The result of handling one of these caterpillars is said to resemble a severe stinging accompanied by painful swelling. It is the only instance of anything like a true sting in the whole realm of butterflies and moths. At Fig. 19 *a* I have drawn a magnified view of one of these spines with the poison gland inside it. At 19 *b* is a still more highly magnified section of the detachable point, showing how it is fitted on to the tubular portion of the spine.

The late Professor Packard described the external features of the poison spines and other armament of some of the so-called 'Limacodid' and other larvae many years ago, though it was only after I had investigated their structure that I discovered his article on the subject. I was interested to find that he had also likened the small many pointed structures to the ancient caltrop. These Limacodid larvae assume the most grotesque forms, and at Fig. 20, *a*, *b*, *c*, *d*, I have shown four species occurring in Ceylon, and copied from my friend Mr. E. E. Green's

original drawings. In the *Transactions of the Entomological Society* of 1894 the late Dr. T. A. Chapman, to whom we owe so much of our knowledge of larval structure, gave a most interesting account of the caterpillar of one of our British species. This larva has

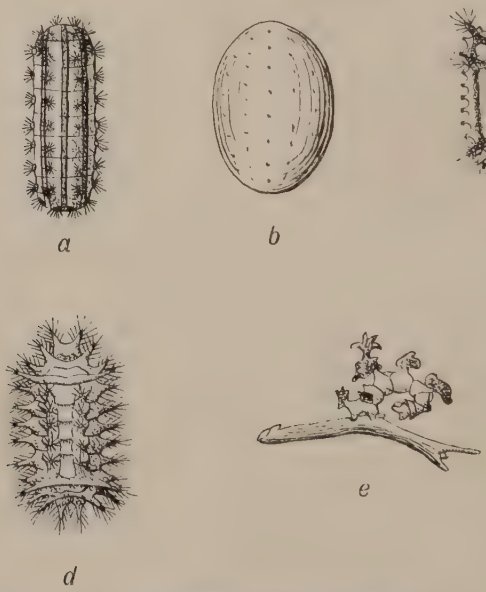

FIG. 20. *a*, *b*, *c*, *d*, curious larvae of four species of Limacodid moths from Ceylon; *e*, a remarkable Geometer larva, also from Ceylon, with bits of leaves, &c., attached to it (after Green).

suckers instead of the usual temporary feet. At the actual moment of hatching from the egg it appears to have no spines at all, but almost immediately it becomes covered with them. This surprising development is possible because the spines are retracted beneath the creature's skin, their tips only appearing as slight surface

marks. They rapidly emerge like the joints of a telescope, and soon harden in contact with the air. After the first moult these spines are replaced by others of a slightly different form.

It is remarkable that protection by special hairs is not a commoner type of defence amongst larvae, since the development of such weapons requires so small a departure from the normal; nevertheless most caterpillars are harmless and defenceless creatures, and the most frequent form of protection is the simple one of concealment. There are, however, certain other developments which in a few species serve as a partial protection. In very many species there exists a gland opening beneath the first segment behind the head. Its normal use is not very well understood, but in certain forms it is developed much more highly and has become an organ of considerable size. A good example is that of the Lobster moth. The name 'Lobster' is really derived from the caterpillar, one of the most extraordinary insects to be found in this country. Why it should have been originally regarded as having the appearance of a lobster is not very clear, for it can hardly be said to resemble that creature at all closely. In its various stages it plays many parts and adopts many strange attitudes; at different times it looks like different objects, but at no time does it remotely resemble a normal caterpillar. Portchinski has suggested that in certain aspects the dilated hinder part gives the appearance of a well-known kind of bug devouring the caterpillar. As the bug is very offensive such an appearance would undoubtedly be protective. I have made a few sketches of it at Fig. 21. Four of its true legs are developed into long trembling

organs totally unlike the tiny feet of other larvae, whilst the hinder end of the body is enlarged into a curious cushioned form with two antenna-like projections. Owing to its long legs and the incessant vibration of the second pair, which are held aloft, its appearance when young is

Fig. 21. The larva of the Lobster moth in various attitudes.

very like that of an ant. Indeed, when showing a brood of young larvae to unentomological friends the verdict of nine out of ten is 'ants'. Until the first change of skin there is but one possible food for the infants, and that is their own egg-shells. Indeed, should they be deprived of this nourishment it is hopeless to expect them to

survive ; the noticeable growth which they make on this slender diet is phenomenal. At this stage the whole surface is so shiny that they have the appearance of having been varnished. As they increase in bulk they lose this high polish. The long legs become longer and the head-like hinder end grows more conspicuous. When at rest they adopt a peculiar attitude. The false head or cushion is folded over the back and the creature hangs by its hind legs. It is dull brown in colour and looks like a bit of dead and twisted leaf. If touched or alarmed it stands on its temporary or hinder legs, raises and bends backward the fore-part of the body, and spreads out its long fore-legs, vibrating them rapidly (see Fig. 21). Exactly what it resembles when in this attitude it would be difficult to decide. In a vague way it suggests a large and dangerous sort of spider, and ichneumon flies would probably avoid such an enemy. The general effect is sufficiently alarming, and added to this is the terror which attaches to the unknown. But the attitude is not entirely deceptive, for the gland already mentioned may come into play. It seems strange that so effective a weapon is comparatively seldom used. Certainly I have handled these strange larvae daily without noticing more than a slight discharge of the liquid which it secretes, but there is no doubt that the creature can, and occasionally does project with some force several drops of what, on examination, proves to be formic acid of considerable strength, a most unpleasant substance in contact with the eyes or other tender surfaces. The discharge would undoubtedly serve to disable a bird or other similar enemy, if efficiently directed. If the larva is handled,

a certain amount of this secretion seems almost always to be excreted, though not violently, and its peculiar acrid odour is probably sufficient to warn some at least of the creature's enemies. Professor Poulton has actually tested the effect of the formic acid discharge of the Puss moth larva on ichneumon flies, and found that they collapsed immediately. It is probably against these enemies that the defence is mainly employed. The parasites, however, have in some cases learnt to overcome this defence, for one of them deposits its egg on the Puss moth larva in its last stage, when it has to a great extent lost its defensive powers. Mr. E. E. Green, late Government Entomologist in Ceylon, tells me that he once observed a plague of a species of 'Lobster' caterpillar in the plantations there, and that the hands of the natives were much affected by the constant discharge of formic acid. There are caterpillars of related species in Africa, some closely resembling our own 'lobster', though Dr. Carpenter informs me that certain other nearly related forms are quite normal in appearance.

One more curious effect may be noticed. The peculiar enlargement of the hinder end of the body with its long projections has a wonderful likeness to the head of some reptile with a forked tongue, especially when this part only is seen projecting from beneath a leaf (Fig. 21). Except for its generally alarming appearance, this feature may be of little service in temperate climates, but there are Lobster caterpillars in the tropics where such an appearance may serve to remind enemies of real and familiar dangers.

Another caterpillar which more often makes use of its formic acid gland is that of the 'Puss moth'. This

larva, like the 'Lobster', combines its one real offensive power with concealment. As a very young larva it is sooty black, but as growth proceeds it develops a very elaborate pattern and colour. The greater part of the

FIG. 22. The Puss moth larva resting amongst willow leaves (from a photograph).

body is green, but on the back is an elongated diamond-shaped patch which on close examination is found to be white crossed all over by fine lines of a purplish colour, and edged with white only. On each side, just above the second temporary leg, is an irregular mark of the same colours. These peculiar markings have the effect

of breaking up the creature's outline, so that in its natural position amongst the leaves of its food-plant it can hardly be distinguished from the mass of green lights and purplish shadows (see Fig. 22). Even when discovered it is not a very alarming creature. It has two rather long spiny projections arising from the hinder end of its body, but these look natural enough. Its head is like that of other caterpillars, and there seems no

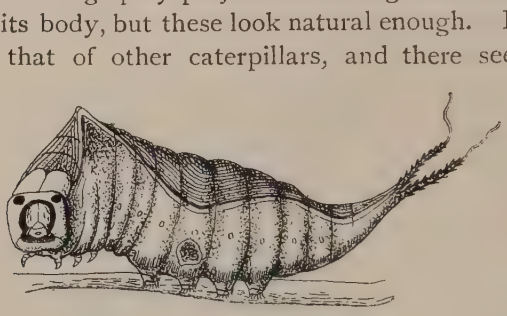

Fig. 23. The Puss moth larva alarmed, showing the false face and the filaments protruding from the tail.

reason why we should not touch it, but do so, and one is irresistibly reminded of the comically fearsome creatures sometimes seen in pantomimes (see Fig. 23). As if from nowhere, a dreadful face appears, red and furious, two large coal-black eyes stare at the intruder, whilst the forked tail rises up to battle and from its points there issue two wicked-looking scarlet threads which twist and wriggle like venomous worms. If at this moment the creature does decide to eject its formic acid, it does not belie its fearsome looks, but like our 'lobster' this last 'frightfulness' is more often held in reserve. The origin of the dreadful face is a fold of red skin round the head which can be suddenly inflated, whilst the black 'eyes.' are merely black spots on its upper portion. The waving

scarlet 'worms' are real enough, for they are filaments hidden in the forked tail, and are forced out by pressure from within. Their real structure is very elaborate and includes a highly complicated arrangement of nerves and muscles which have been beautifully illustrated by my friend Professor Poulton, in the *Entomological Society's Transactions* for 1887. Indeed, we may well marvel that nature should have evolved so elaborate a mechanism merely to produce a fraud, for it is quite harmless, just as the nightmare face is not real and the eyes but painted spots. Perhaps the truth is that in the struggle of nature a fright is often a sufficient warning. Experimental investigation into the reality of apparent dangers is apt to result in serious consequences to the experimenter. For the wild creature whose life is short and whose knowledge is limited to personal experience, too persistent a search after truth may mean death, or a disablement which ultimately will amount to the same thing. We ourselves learn much by accumulated knowledge and a fraud once exposed ceases to be effective for us. In the wild the Puss moth's joke is ever new, for its victims are always unsophisticated.

In these two species, I have spoken of the formic acid gland which is a real defensive weapon. The 'Gold-tail' caterpillar and all its near relations possess two small eversible glands on the back. They are of quite elaborate construction and consist of a kind of bag which is normally drawn in and not at all conspicuous. When irritated, however, the larva can turn them suddenly inside out, and they appear as scarlet beads covered with a moist secretion. The fluid is not present in sufficient quantity to enable us easily to decide its nature. Some

observers maintain that it gives off a powerful odour, though the writer has not been able to detect this. Possibly it may be adapted to the selective sense of smell of some enemies. That it is of considerable importance seems sufficiently proved by its structure, which I have shown at Fig. 24. The picture is really taken from

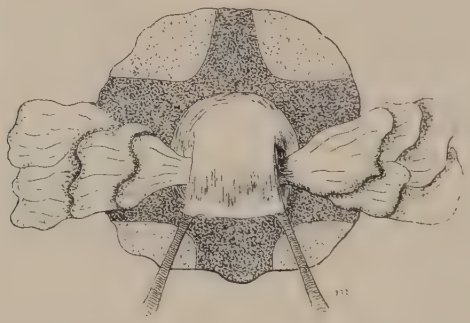

Fig. 24. One of the glands on the back of a Vapourer moth larva as seen from the inside of the skin. The bag-like structures are parts of the gland which, in the centre, can be protruded by internal pressure, and withdrawn by the muscles *m* (magnified).

the similar gland in the Vapourer moth larva. Fig. 25 is a section through the whole apparatus which shows the two actual glands leading into the eversible bag. Fig. 24 is a view of the bag itself as seen from the underside of the skin, with the little muscles (*m*) by which it is withdrawn.

The best example of a gland of this kind which produces a scent very perceptible to our senses is the forked tube which the caterpillar of our 'Swallow-tail' butterfly can extrude from just behind its head. When the insect is at rest there is no sign of this organ, but if handled, the creature will often eject it very suddenly,

when the neighbourhood is immediately pervaded by a peculiarly sickly smell, which has been aptly described as resembling rotten pineapples. The caterpillar is of a beautiful apple green colour with velvety black bands and orange spots. No doubt it is distasteful to birds, and the peculiar smell of the gland may serve as a reminder to them of past unpleasant experiences. The caterpillars of all species of the Swallow-tail butterflies, so far as they are known, possess this mode of defence.

Fig. 25. Section through the gland of a Vapourer moth larva, showing its cellular structure.

In describing the Puss and Lobster moths I have instanced two of the commonest and most instructive examples of protection by terrifying attitudes and appearances. There are others less well known. The larva of the Great Elephant Hawk moth has large eye-like markings on the fore-part of the body. These are some distance behind the real head and normally do not suggest anything very alarming, but if disturbed the creature suddenly withdraws its head and front segments causing the remainder to swell up and bringing the large eye spots forward. It then appears to have a large snake-like head with two great eyes. The effect is enhanced by white specks on black patches which give the appearance

of the bright spot of the eye. Considering the natural form of a caterpillar it is rather remarkable that resemblance to snakes is not a commoner deception. Bates, as quoted by Wallace, described a very large caterpillar in South America as the most extraordinary instance of imitation he had ever met with, which stretched itself from amidst the foliage of a tree which he was one day examining and startled him by its resemblance to a small snake. The first three segments behind the head were dilatable at the will of the insect, and had on each side a large black pupillated spot, which resembled the eye of a reptile ; it was a poisonous or viperine species mimicked; as was proved by the imitation of keeled scales on the crown, which was produced by the recumbent feet as the caterpillar threw itself backwards.

An even more striking resemblance to a snake is presented by the larva of one of the Bornean Hawk-moths, described by the late Robert Shelford. As his account is rather technical, I give a summary of it in somewhat less scientific terms. The general colour is dark olive-brown, with the fore-part somewhat paler. At the junction of the third and fourth segments is a large eye spot, almost the exact size of the eye of a snake common in that country. The black of this spot appears so intense and glossy that it is difficult to believe that one is not looking into a real eye, especially as the lower edge is bordered with bright gold, the colour of the iris in many snakes. The effect is to give an upward glance to the eye. Running through the eye spot there is a broad black stripe, which is also present in the painted snake of Borneo, whilst a wrinkled fold on

each side of the lower half of the second and fourth segments suggests an impression of upper and lower jaws. The segments are flattened like the head of a snake, while delicate markings imitate the outlines of scales.

I regret that no picture of this larva is at present available. It is probably the most perfect imitation snake to be found amongst caterpillars.

So far we have dealt with defences of caterpillars which are either real offensive weapons or alarming appearances intended to be seen. Such methods are however in a minority, and of all the means of combating the innumerable dangers which threaten the caterpillar's life, the most favoured is that of concealment. Prevention was ever better than cure, and how much better never to be discovered than to risk the outcome of a real encounter. I have already mentioned caterpillars which feed only at night. There are very many of these, as the distracted gardener can testify. The pelargoniums that were intact yesterday are riddled with holes this morning, yet not a culprit is to be seen. There is nothing for it but to seach for them with a lamp. Generally these night feeders are very inconspicuous. Some bury themselves by day, others do not really hide at all, but are so perfectly shaped and coloured to resemble inanimate objects that they are passed over without detection. They would be noticed if they moved, hence they remain all day perfectly motionless. Before describing some of these forms which are common in our own country, I may mention one remarkable South American species. It is the caterpillar of one of the Morpho butterflies, most of them gorgeous metallic

blue creatures, six inches or more across the wings. The caterpillar is very beautifully arrayed in green and crimson and is naturally of considerable size, but it is a night feeder. Why then the splendid garments? Its habits are curious. Several individuals choose a leaf and, after eating all but the midrib, mass themselves on it in a cluster. Such behaviour would be fraught with the danger of a bad fall when their support withered as it must rapidly do. But their instinct is not so faulty. They take the precaution of fastening the remains of the leaf securely to its twig by sewing it on with silk. This is their abode during the day, and in some way not yet explained they are able to find it again in the morning, after their nocturnal rambles. Hanging on their support, and massed together, their green and crimson colours have a surprising effect, for their discoverer states that in this position they simulate a very beautiful flowering orchid.

It is unfortunate that the caterpillars of comparatively few tropical butterflies and moths are known, for we have good reason to expect that many remarkable examples of protection will be found amongst them. Insect life in the tropics is more strenuous than with us; the struggle for existence is keener, and hence abnormal forms are likely to be of more frequent occurrence. To turn to examples of protective resemblance common in our country, mention must be made of the many instances in which caterpillars resemble sticks or twigs. This is the commonest form of concealment in the 'looper' or Geometer caterpillars already referred to. At Fig. 26 I have shown a number of these. There are five species of these caterpillars represented, and it will be seen that

their shapes are beautifully adapted and modified so as to give them a variety of twig-like appearances. They

FIG. 26. Stick-like caterpillars: 1, Oak Beauty; 2, Peppered moth; 3, Lunar Thorn; 4, Purple Thorn; 5, a Continental species (*Respersaria*).

belong to various species of moths such as the 'Oak Beauty', the 'Lunar Thorn', the 'Peppered moth', &c. In nature they would not all be found on the same branch, as of course they feed on different plants. They would also, on their natural background, be very much less conspicuous than in the drawing. It is unfortunate that expense precludes their reproduction in the natural colours, since the wonderful arrangement of the tints and shades is one of the most remarkable features of this form of protection.

There is, too, the surprising power which most of these larvae have developed of adapting their colours to their surroundings. It is true they cannot, like the chameleon and some other animals, change their colours in a few minutes, but if larvae from the same batch of eggs be reared in different surroundings they will develop by degrees a colour which comes very near to matching that of the surface on which they habitually rest. To take one of the simplest examples, the caterpillars of the common Peppered moth, if reared in white cages, with white twigs on which to rest, become paler and paler until they attain a kind of silvery grey. Others of the same brood placed among black twigs will become black, whilst those in well lighted green surroundings develop a bright green colour. Still more remarkable is the way in which some larvae when kept on speckled lichen-covered bark will develop not merely the colours, but a pattern, of just such an irregular nature as that of their surroundings. Mere descriptions of these colour adaptations are neither very interesting nor convincing, and the reader who is anxious to pursue the matter will do well to turn to the beautiful coloured plates accompany-

ing Professor Poulton's account in the *Transactions of the Entomological Society* for 1903.

In addition to caterpillars which really hide, or else conceal themselves by appearing to be what they are not, there are others which live all their lives inside trees, eating the wood and boring galleries in all directions. One of the best known of our British species is that of the Goat moth, so called from the goat-like smell given off from the tunnels in which the larva lives. It is a large caterpillar, cream coloured beneath and brick-red above, and is said to spend some three years or more in its wood-eating state. Sometimes it migrates from its ancestral tree when the time comes for pupation, and forms a cocoon in the ground, though for so conspicuous a creature this voyage must be one of considerable danger unless its peculiar smell affords it some protection. The pupa is generally hidden in a burrow made by the caterpillar, though, just before the large grey moth emerges, the pupa itself wriggles its way to the outlet and its forward end projects slightly. It might be supposed that such a caterpillar enclosed in its wooden galleries would be safe from the deadly ichneumon fly; but no, evolution has enabled these parasites to keep abreast of the devices of their prey, and armed with long egg-laying tubes and effective boring appliances they find the hidden larva by some sense which we cannot emulate and patiently drill down to its defenceless body. Other wood-boring larvae in twigs are found by birds and torn from their hiding-places. Sound may betray them, for the bird is probably able to hear the tiny jaws at work below the surface.

It may be thought that the wearing of clothes is a

peculiarly human invention, but long before there were human beings, insects had solved the problem of the manufacture of protective garments. Probably the earliest human garments were merely intended as personal adornments, and had little utilitarian purpose. It may even come as a shock to those whose ideas have been narrowed by prejudice and long custom to learn that there still exist races of a high moral code who regard the undue covering of the human form as an offence against decency. But our insect dresses are not the outcome of any vanity and would more properly be described as a form of fancy dress, or perhaps as a coat of mail. To be recognized is, for the caterpillar, almost certain death, and, as we have seen, most of those which survive have done so largely by misrepresenting their true nature. The incomparable Henri Fabre has described the sartorial activities of the 'Psyche' moths in a manner which it would be a mere impertinence to emulate, and I would counsel those who are unfamiliar with his works to use these pages merely as a passport to the realm of romance which his patient labours have revealed. The young larvae make their first dress from the materials of the old one in which their mother lived, for she is hardly recognizable as a moth, and never leaves the covering she made when a caterpillar. This old garment is made of tiny sticks interwoven with silk. The little caterpillars bite out the pith from these and make it into small pellets, fastening them together with their own silk. Having made a band of this, each passes it round its body and fastens the ends with more silk. Gradually adding to the edge of this girdle, the caterpillar moves forward within it, so that, to borrow Fabre's graphic

description, the garment is first a scarf, then a waistcoat, then a short jacket, and lastly a sack or conical hood. The materials which Fabre offered to the larvae were varied in several ways and they made their cases of blotting-paper, cork, the scales from a moth's wing, and powdered iron ore. As the winter approaches the covering is increased by the addition of straws and bits of leaf, at first irregularly, but later attached neatly by one end and all pointing backwards.

As already stated, the females of these moths are hardly recognizable as such, being indeed very degenerate creatures, consisting of little more than an egg-bag. The eggs are deposited in the case and what is left of the mother shrivels and dries up. There are many different species and the cases are constructed in correspondingly varied ways. At Fig. 27 I have drawn a selection of these. Some are of the roughest design; others, such as Nos. 4 and 5, are neat baskets made from little sticks all cut to the same length, and fixed in a regular manner. Amongst the most curious are those of the form of a snail-shell, as No. 7, and made either of pure silk, or of earthy particles fastened together with silk. No. 1 shows a dress made of a lining of silk and a trimming of bits of grass, leaves, and so on. No. 2 is woven from very fine straws or stems. No. 3 is a mere bundle. No. 6 shows the progressive growth of the case, the more recently added portions being of large diameter to suit the increasing size of the wearer. So great is the variety of 'fashions' that many plates could be devoted to their illustration. Some are like neat bundles of faggots; others, mainly of silk, have a regular form resembling seed-pods and other vegetable growths. One

is a straight trumpet of silk, others, again, mere masses of leaves. Though most of the species are small there

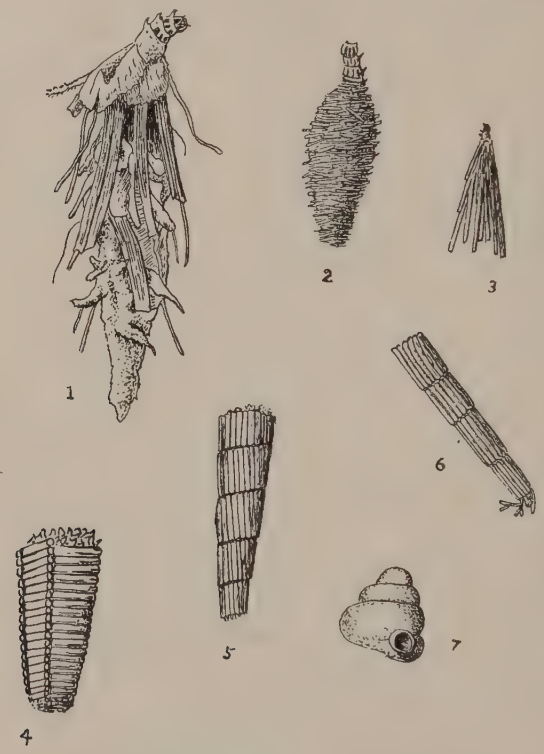

FIG. 27. Larvae of Psyche moths, sometimes called basket worms, with their cases. In No. 1 the case is made from a miscellaneous collection of objects with a silken bag at the end. Nos. 2 to 6 are made of small stems, sticks, &c., in various styles. No. 7 resembles a small shell and is made of silk and fine earth.

are giants amongst them, and one of these makes a silken sack four to five inches long with what, by

comparison, may be called veritable logs of timber incorporated with the fabric. Fig. 28 is a magnified view of an interesting costume made by the larva of a small British species (*Coleophora*). I have shown the head and first segments extended from the neck of the 'bottle'.

The male Psyche moths are winged, but generally of very dull appearance. One species is remarkable for the peculiar arrangement of the grey scales on its wings. The moth is about an inch and a half across, and so of quite appreciable size, but the grey colour only exists as a small irregular patch near the body, the remainder of the wings being thin and perfectly transparent. I have no details of its habits, but we may suppose that the effect is to make a comparatively large moth appear to be extremely small, since the greater part of the wings is practically invisible.

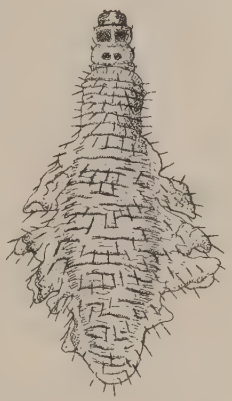

FIG. 28. Larva of a small British moth, *Coleophora* sp., with its dress made of bits of hairy leaves (magnified).

In Ceylon there is a larva of one of the Emerald moths which, though it does not make a complete case, nevertheless succeeds in making itself almost unrecognizable as a caterpillar. I have shown it at Fig. 20, *e*, p. 52. It has on its body numerous small projections to which it attaches pieces of dead leaf and other débris. When at rest it adopts the peculiar attitude shown in the sketch.

Of all the curious known defences of caterpillars, one of the most unusual is that adopted by a little moth larva discovered in South America by a friend of the

writer, the Rev. A. M. Moss.[1] This collector found a large larva of a moth related to our Emperor moth. As is common in species belonging to this family, the caterpillar is protected by long branched spines. Between the segments of the body were black bands, some of which had a swollen appearance. Mr. Moss was astonished to find that the swollen black markings, when touched, rapidly slid over the caterpillar's back to the other side! They were in fact small caterpillars apparently of the 'Pyralid' order. So quickly did they move that they were exceedingly difficult to catch. The large caterpillar actually has black bands between the segments, but these little larvae are of precisely the same colour and appearance and so are hidden by attaching themselves in these positions, whilst they are doubtless protected by the large spines of their host.

Moth caterpillars are not always terrestrial, and the family known as the Pyrales contains many species which live in water. One of these, *Nymphcata*, mines in the leaves of water plants for a day or two, but after its first change of skin it makes for itself a case by fastening a piece of leaf to the underside of another leaf. In this it passes the winter. Up to the present it has contrived to breathe through its skin, which apparently has the power of absorbing the oxygen dissolved in the water. In the spring, after moulting, it develops peculiar roughnesses which enable it to keep a coating of air on its surface; it also makes a new and portable dress from two pieces of leaf fastened together with silk, and in this it is able to hold a further supply of air. Its tracheal

[1] The same or a similar case seems to have been observed by Dr. F. Müller about 1877.

tubes, hitherto closed, now become open and it breathes in the same manner as terrestrial caterpillars. When feeding, the leaf case is moored to the food-plant by a silk thread. Finally, a new case is made in which it changes to the chrysalis. This moth lives on land, but in another species, an insignificant little whitish moth, *Niveus*, the female actually lives in the water and the male follows her beneath the surface.

There are, in fact, few places in which moth caterpillars may not be found, and amongst their habitats may be mentioned the corks of wine bottles, which are often damaged by the larvae of a small moth (*Oinophila*), bees' nests, in which several species are parasitic, and the hair of the three-toed sloth in South America. The sloth's hair frequently has upon it minute vegetable organisms, and it is thought that these may provide the larvae with food. There is even a caterpillar which takes possession of the galls made by a species of *Chermes* (a 'plant louse' or 'green fly') on plants of the Spurge tribe in Argentina. These galls do not always provide an adequate supply of food for the intruder, and it then emerges in search of a leaf. It does not, however, consume it in the open, but, dragging it to the entrance of its retreat, sews it on with silk and consumes it from the inside of its shelter.

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V

THE CHRYSALIS STAGE

In due time our caterpillar has eaten its fill and has grown to its full size. It must now enter on that stage when it will eat nothing and move little, if at all. It will be, perhaps for a long period, even more defenceless than it was as a larva. In addition to dangers from living enemies, it will have to withstand all the changes of the atmosphere, including, probably, hard frosts. Some species have but a few weeks of summer to endure, but for very many species, at least the winter will be passed in this stage, and more rarely two or even three years. Frost would seem to be amongst the least of dangers for the average chrysalis. The pupae of the Cabbage Whites, of the beautiful Swallow-tail, and many others, must frequently be frozen hard, and yet they survive, and these have no protective cocoon of silk nor underground retreat. Intense cold would seem to have little effect on our Northern species, and Sir George Nares found five species of butterflies in lat. 78°–83° N. The preparation for the change to the chrysalis state varies much, of course, with the species. Great numbers of moth larvae bury themselves in the ground, where they may make a slight or considerable cocoon of silk. Others fasten together leaves, either on the tree or on the ground. Those, such as the Goat moth, which live in wood, generally pupate near the exit of their burrows. Very few

butterflies make a cocoon. The beautiful 'Apollo' butterfly, with scarlet-ringed semi-transparent wings, is amongst the exceptions, making as it does a slight case of silk for its pupa.

Butterfly pupae are sometimes formed on the ground without any special protection. More commonly they are suspended, either in an upright or horizontal position, attached by the posterior end and supported by a silken

Fig. 29. Larva of the Swallow-tail butterfly ready to become a chrysalis. Note the belt of silk round the upper part and the silk pad to which the tail is attached. The second figure shows the chrysalis after the larval skin has been shed.

girdle, or in an inverted position attached only by the 'tail'. The former method is that adopted by all the species of Papilios or 'Swallow-tails'. At Fig. 29, *a*, is a drawing taken from a photograph of the larva of our British

Swallow-tail as it appears when ready for the change to the pupal form. The creature first weaves a thin layer of silk over the support, making a somewhat thicker pad at the point where its last pair of temporary legs are attached. It then proceeds to make the girdle, in this fashion. Clinging by its temporary legs, it bends the anterior part of its body backwards, at the same time moving its head from side to side so as to attach the silk to the support at the end of each stroke. When the girdle is sufficiently strengthened it resumes its upright position and the anterior segments of the body are bent forwards and downwards. It then becomes perfectly still, and it is this stage which is represented in the figure. It shows little outward change for perhaps two or three days, but the internal processes must be rapid and considerable. The chrysalis skin is formed beneath that of the larva, and the whole substance of the head and first segments is withdrawn from that part of the larval skin, the head of which becomes an empty shell. At length the pupa is completely formed and separates from the larval skin, which seems to shrink. The shedding of the skin, once begun, is very rapid. Partly by shrinkage and partly by the movements of the chrysalis itself, the skin is passed beneath the girdle, which now adheres to the soft moist pupa. Apparently supported by this, the larval skin is shaken off and the 'tail' of the chrysalis is attached to the silk pad. It then appears as in Fig. 29, *b*.

When a chrysalis is suspended in the inverted position, as in our Vanessid butterflies (Peacock, Tortoise-shell, &c.), the larva first attaches a pad of silk to its support, and hangs there by its last pair of claspers. The anterior segments are curved over so that the larva presents

a hook-like shape. As the pupa emerges the larval skin recedes, but before it becomes entirely detached from the chrysalis the extreme end of the latter, which bears a cluster of minute hooks, is thrust out and becomes entangled in the pad. A delicate membrane is said to act as a bond between the chrysalis and the caterpillar skin during the critical moments when the pupa is attaching its hooks to the silk.

Scudder has remarked that where the pupa hangs loosely in this inverted position, and is therefore liable to swing about and strike against neighbouring objects, it has projections on head and thorax which will protect it from injury. Certainly such pupae are generally of irregular shape, with horn-like growths, and though in many species they would seem to serve in breaking up the outline, and so making the pupa inconspicuous, they may act also as buffers when required. All pupae when first formed are soft and defenceless, though the skin rapidly hardens in the air and usually darkens in colour. The soft stage is one of great danger to the insect, since enemies are ready to take advantage of it, and Professor Poulton has observed a parasitic insect, known as a Chalcid, waiting beside a Tortoise-shell larva which was about to pupate, presumably in order to attack the pupa when still soft. On another occasion the female Chalcid was found seated on the fresh moist pupa of a Red Admiral. We must regard the pupa as the Chalcid's legitimate prey, but it is sad to relate that certain caterpillars, easily tempted from their more regular vegetarian habits, will take advantage of the defenceless among their own species. The collector who would successfully rear our little Holly Blue will do well to remove from the

feeding cage all larvae which show by their darkening colour that they are ready to pupate, lest the soft and delicate newly-formed pupae be treacherously attacked and sucked dry by their less mature brothers and sisters.

Pupae not protected by thick cocoons or buried beneath the ground are generally very inconspicuous. An exception is furnished by that of the Magpie or Currant moth, whose pupa is hung in a very thin and transparent cocoon and is easily seen owing to its bright yellow bands on a black ground. Whether it really imitates a wasp or merely exhibits the well-known warning colours of black and yellow need not here be discussed. The larvae, pupae, and moth are all very distasteful to insect-eating birds, and it is probably to the advantage of the pupa to be easily recognized.

No sooner is a pupa formed than the position of the wings, legs, antennae, &c., of the perfect insect can be clearly seen on its surface though it may be long before these parts are really formed within. In some primitive forms the appendages of the pupa remain more or less free, but in the great majority they are immovable and adhere to the body. In some forms the pupal wings show vestiges of ancestral patterns and structure which are lost in the perfect insect.

Many moth larvae make cocoons of silk or other material for the better protection of the chrysalis, and the best-known examples of this habit are the silkworm moths. Commercial silk is obtained from several species, but that most generally used is produced by the larva of the small whitish moth known to men of science as *Bombyx mori*. There is an enormous literature devoted to this species alone, and the cultivation and preparation

of the silk is one of the world's great industries. The caterpillar makes three separate cocoons, the inner one thin and papery, the middle one tough and dense, and the outer covering loose and fluffy. It is from the intermediate layer that commercial silk is obtained, and it consists of a single unbroken thread of an average length of some fifteen hundred feet.

Fig. 30. Diagram of the cocoon of the Emperor moth to show the 'eel-trap' arrangement of stiff bristles at the narrow end.

The majority of cocoons are silken cases of simple structure, but in that of our 'Emperor' moth we have an example of a more elaborate and interesting form. It is shown diagrammatically at Fig. 30, and is somewhat pear-shaped. At the narrow end the outer covering forms a neck or tube loosely closed by a tangle of silk. At first sight it would appear an easy matter for an enemy to make its way through so ill protected an opening, but if the loose silk be removed we discover a most efficient barrier. Within the narrow portion is a ring of stiff bristles formed of thick and specially hardened silk. These bristles are directed outwards, and, inclining together, meet in a point at the centre. Obviously the moth can emerge from within by pushing aside the bristles, but the device forms an exit only, and no entrance. In making this cocoon the caterpillar first constructs the outer case, including the bottle neck and its loose tangle of silk. Then it makes the 'eel-trap' structure by spinning backwards and forwards several times for each bristle, which consists of many threads cemented to-

gether. It is probable, though I have not been able accurately to observe it, that the inner threads are made shorter, thus causing the bristle, as a whole, to bend inwards at its free end. Certain observations on the instinctive actions of insects have shown that if the usual course of their operations be interfered with, they are incapable of repeating their work to make good any damage. Thus Fabre, as already mentioned, found that his Pine Processionary caterpillars did not repair their winter nest when he had cut a hole in it. Such lack of adaptation is not universal, as would appear from a small observation of my own on the Emperor moth larva. In endeavouring to observe the precise method by which the insect made its 'eel-trap', I cut away with fine scissors the outer part of the bottle neck of the cocoon, which it had just made. My curiosity was not, however, to be so easily satisfied, for the larva at once proceeded to renew, and did in fact replace, the portion I had removed. Once when rearing about seventy or eighty of these larvae, one caterpillar constructed a completely enclosed cocoon without any bottle neck, a perfectly spherical structure without any egress at all. Thus instinct is sometimes faulty. In nature the enclosed moth would not be able to escape, and since it could not reproduce its kind such erratic tendencies would be suppressed.

It was my intention in the spring to cut open the cocoon before the moth emerged, and, when it did so, to breed from it, in order to discover whether its defective instinct would reappear in any of its offspring. Alas, I was too late. Its faulty constructive sense seemed to combine with a tendency to hatch out before its fellows, for when I cut open the cocoon I found that the moth

had already emerged and perished in its gateless prison.

In West Africa there occurs a moth somewhat resembling our Oak Egger, but of a pale yellowish colour, with a pattern of delicate brown markings. The caterpillar is very hairy and has also an armament of spines. With these and with silk it constructs an elongated cocoon from near one end of which protrude two bundles of hairs having the appearance of horns. But a more remarkable feature of the structure is the barricade which the larva constructs, presumably to ward off the attacks of ants. The cocoon is attached to a slender stalk or twig, and above and below it the larva constructs a somewhat lengthy entanglement of loose hairs and silk in which small enemies approaching from either direction must inevitably be overwhelmed.

An example of a more peculiar cunning is that of the Lanaria moth, discovered in West Africa by my friend Mr. Lamborn. The chrysalis when formed is green, and the caterpillar makes its golden-yellow and very thin cocoon on the surface of a green and living leaf. When its operations are completed all that is visible is an apparently empty cocoon, obviously of no interest to a hungry enemy. This empty bag is sufficiently transparent to permit the observer to see right through it. But it is merely a deception. The chrysalis lies under the lower surface of the empty cocoon, its green colour merely increasing the perfection of the illusion. Fig. 31 is a sketch of one of these cocoons in its position on a leaf.

Another curious method of defence is that of the Varia moth discovered by Dr. G. D. H. Carpenter. Its

larva is warningly coloured, the most striking feature being certain pale blue spots which are extremely conspicuous. The cocoon is thick, soft, and velvety, being made from silk mixed with the larval hairs. The hinder end of this cocoon is provided with a small opening, and after the chrysalis is formed within, a part of the larval skin is thrust through this aperture, where it appears as a danger signal. There can be little doubt that the

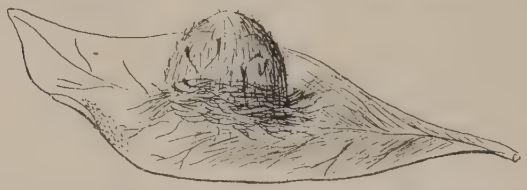

Fig. 31. False and apparently empty cocoon of an African moth (*Euproctis lunaria*). The chrysalis is really under the layer of silk on the leaf.

larva is very unpalatable, and its appearance is probably well known to birds and other insectivorous enemies. The cast-off garments are thus used as a warning and probably confer some additional measure of protection on the pupa, already well protected by its thick woolly cocoon.

Probably the most curious cocoon yet discovered is that of a black-and-white moth, also found by Mr. Lamborn in West Africa (Fig. 32). It has already been explained that larvae suffer from the attacks of parasites which, when their host is fully grown, make their way out and, each weaving its own tiny cocoon, surround with a mass of such small objects the remains of the caterpillar skin. It may be readily understood that insect-eating birds will in time come to recognize

such masses as unprofitable food. The proportion of silk to edible material is too great to make it worth while to pick them to pieces. Now this caterpillar makes a thin cocoon, but covers it with little balls of a whitish appearance, finally retiring within and resting securely beneath its disguise. The discoverer of this cocoon, under the impression that it was a mass of parasites, actually took it home, hoping to hatch them out and determine their species. Only when a healthy moth appeared did he realize his mistake and the caterpillar's deception. He afterwards obtained the larvae and watched the whole process of construction. In this case we have a species which avoids one enemy by simulating the appearance of having been already destroyed by another.

Fig. 32. Cocoon of the African moth *Deilemera antinorii*, covered with imitation parasitic cocoons.

And here we must give a word of warning to the reader who is unfamiliar with the actions of insects. It is not to be supposed that our caterpillar is familiar with the appearance of a parasitized member of its tribe, or that it carries out its complicated deception with a knowledge of its enemies and their habits. Even were we to credit so lowly a creature with such advanced powers of reasoning, it must be obvious that a caterpillar which has been victimized by parasites would hardly be in a position to profit by the knowledge so disastrously acquired. Such a creature, even if gifted with observation and memory, could never learn from experience, for the experience would terminate its life.

Did we know only one such instance, and that as highly developed as is the example quoted, the origin of the habit would be difficult to imagine. We know, however, that other larvae strengthen or thicken their cocoons with various excretions, or with particles of extraneous material. In the present example the auxiliary structures happen to resemble something which affords additional protection, and so by selection the habit has been perfected and perpetuated. As an example of a different kind of cocoon, highly protected partly by its close resemblance to its surroundings but still more by its mere mechanical property of extreme hardness, we may take that of our own Puss moth, already referred to as remarkable in the caterpillar stage. The construction of this cocoon is an extremely interesting process and easily observed. When fully fed the delicately coloured larva loses its green tint and becomes of a purplish hue. It selects a site for its cocoon, in nature usually on the bark of a tree. In captivity it will choose cardboard, cork, or even a hard wood board. Slowly it weaves its silk covering; the result is not a continuous fabric, but resembles a very fine net with a multitude of minute openings. Having reached this stage it turns back to the support on which it began its operations. If it be hard wood the tiny but powerful jaws can be heard rasping off small particles. As each piece is separated it is transferred to one of the holes of the network, where it is retained by the adhesive property of the silk, and by the additional application of a fluid solvent with which the creature appears to lick it. The fluid may probably be formic acid from the gland already described (p. 58). Gradually the whole cocoon becomes a felted

mass of silk and wood, a compost of glue and sawdust. The difficulty of observing such a structure in a crevice on a tree may be easily imagined. At first it is comparatively soft, but it rapidly stiffens and darkens till it becomes so hard that it is difficult to push even a penknife through it. If we keep our hard cocoon till the spring we may find one morning the beautiful moth sitting beside it, having made its way out as though soft fur were an ideal material for cutting through hard waterproof glue. How has it performed this apparent miracle? We have already seen that the caterpillar secretes formic acid in a special gland. The Puss moth is in truth a living chemical laboratory, for, as Latter has shown, at the moment of emergence the moth ejects a drop of strong caustic potash on to the end of its hard cocoon. Few organic materials will resist the corrosive action of this powerful alkali and the cocoon is rapidly softened and pierced.

Why then is the moth's own head not damaged by the fluid? If we are fortunate enough to see it actually making its way out we shall see that it appears to have a black head, but it is wearing the top of the chrysalis skin as a helmet. Apparently the soldier's 'tin hat' is an even older idea than we had supposed. Mr. O. H. Latter has shown that this part of the chrysalis skin is also used as a tool for cutting the cocoon already softened by the fluid. The shield is held in place by special hooks, but is easily removed by the moth's legs when no longer required.

Inorganic chemical substances are secreted by certain caterpillars and used in the formation of their cocoons; thus the Lackey moth cocoon, which is smooth and egg-

like, contains a yellow powder which Professor Poulton has shown to be calcium carbonate in the form known as Aragonite. The same author has shown that the very compact cocoon of the Small Egger contains only a comparatively small amount of silk plastered with a hardened paste of calcium oxalate. This substance, as also the calcium carbonate spoken of above, can be found in considerable quantities in the mature larva just before it is ready to pupate. It occurs in that portion of the insect which corresponds to the kidneys of the higher animals, and is evidently excretory in its nature.

In many of the softer cocoons, the end at which the moth will emerge is of looser texture than the rest, and the moth can force its way out by mere pressure, as does the Gold-tail moth already described. Others construct a cocoon which has the end like a flattened tube. This enables the moth within to force apart the edges without any great effort, though entry from without is by no means so easy.

The African Urda moth, whose caterpillars, as we have seen, are provided with many defences, has a smooth brown egg-like cocoon into the fabric of which are woven the 'bottle stopper', or hypodermic poison spines; under a lens the surface is seen to bristle with these and also with the heavily barbed urticating spicules which accompany them. When the moth makes its way out the end of the cocoon is found to be neatly cut off as though turned in a lathe, and indeed the process is similar in kind. On the head of the pupa is a hard-pointed projection, and it would appear that the creature revolves inside the cocoon until this projection, acting as a cutting edge, has scraped through the hard fabric. On each

segment of the chrysalis is a ring of stiff short spines, and these enable it to grip the smooth internal surface of the cocoon whilst the cutting is taking place. There is some reason to suppose that in certain species the caterpillar in spinning its case leaves a ring of thinner material at the anterior end, so that this is easily broken off as we might break off the end of an egg-shell.

In all these examples, the moth having once made its way out of the cocoon is free and ready for the process of drying its wings, but when larvae bury themselves in the ground there is a far greater obstacle to be overcome, namely, that of the earth beneath which they lie. Some species, such as the Ghost moth, certainly make their way, in the pupal state, to the surface before emerging. Others would appear to hatch out beneath the ground and afterwards make their way upwards, though it is not clear how so delicate a creature as a moth is able to perform, without injury, so laborious a resurrection. The late Dr. Chapman showed that many such moths eject a softening fluid at the moment of emergence, though the quantity of this is so small that it is difficult to account for its doing more than moisten the surface of the cell in which the pupa lies. The fluid has been found to be a solution of potassium chloride.

Fabre has described the digging-out process of the Pine Processionary moth. In the first place that rapid expansion of the wings so usual in species which are born in open surroundings, would here be a serious if not a fatal handicap. It is therefore long deferred, often for as much as twenty-four hours. The moth on emerging occupies but little space: wings and antennae fit closely to the body and only the legs are free. It has

on its head certain hard projections which act as a boring tool. With these the moth breaks away small particles of the earth above it and thrusts them downwards with its feet. In this manner it was observed to bore its way through some ten inches of hardened sand to the surface, the observation having been made possible by placing the pupa in a long glass tube.

Fig. 33. Two curious pupae of African Butterflies (*Epitola hewitsoni* and *Teratoneura isabellae*). Both are allied to our 'Blue' butterflies. (Slightly magnified.)

Probably other species which emerge to find themselves buried escape by similar methods. So far as I am aware no butterfly caterpillars, except some of those which inhabit ants' nests, bury themselves in the ground. Very few make a cocoon, and these differences of habit make an important distinction between the moths and butterflies.

Pupae of many species of Swallow-tail butterflies

resemble leaves and are most difficult to find, though quite openly attached to the food-plant. Perhaps the greater number of abnormal pupae are to be found amongst the tropical relatives of our 'blue' butterflies, two examples of which I have drawn at Fig. 33.

The first is that of Hewitson's butterfly found in West Africa. It is attached by the posterior end at right angles to a twig, and round the point of attachment there remains the discarded caterpillar skin, full of needle-like spines.

This alone is a protection, but the pupa itself is so curiously shaped, and its markings of so 'futurist' a pattern, that all its outlines are broken and distorted, and in its natural surroundings it must be virtually unrecognizable.

The second is the chrysalis of the Isabella butterfly from the same region. Though fairly recognizable as a chrysalis, it is covered with minute growths of a whitish colour, and in addition there are (growing apparently from various points) longer projections of a more or less fungoid appearance. The general effect is to give the impression that the creature is dead and in an advanced state of mouldiness, and but for the habit of examining new specimens with a low-power microscope before treating them in any other way, I should certainly have begun operations by endeavouring to clean off the 'mould'. I was afterwards interested to find that its discoverer had also remarked on its mouldy appearance.

A third example of a curious pupa is that of the Maesa butterfly, an African species. In this instance we have obviously an imitation of a gall from which the gall insect has already emerged, by 'holes' which on closer

examination prove to be merely blackish depressed areas of the pupal skin.

One notable example of protective resemblance in a pupa in this country is that of the Black Hairstreak butterfly, which so exactly resembles a small bird dropping as to deceive even the experienced collector.

WORKING MEN'S COLLEGE

VI

STRUCTURE

We cannot here follow all the details of the gradual changes which take place within the pupal envelope, but it may be noted that the first rudiments of the wings can be detected even in the caterpillar, though as they are internal at that stage they can only be discovered by dissection.

As the time approaches for the emergence of the butterfly the pupal skin appears to become thin and papery, owing to its separation from the tissues of the insect beneath. Very shortly before the actual breaking of the envelope the pattern and colour of the wings can often be seen beneath the outer covering. This pattern is formed of minute scales which are developed from cells on the wing membranes. The scales in their early stage are little bags made from the substance called chitin, which is the basis of all hard insect structures. They are at first colourless, but later filled with a fluid which deposits the colouring matter within them. In the pupa the wings are very small, but immediately the insect has made its way into the open, they begin rapidly to expand, as described in an earlier chapter. This rapid expansion of the wings is a wonderful and interesting process, and takes place in the following manner. The wing has an upper and lower membrane and is

strengthened by a system of thickened hollow ribs called veins or nervures, both unfortunate terms, since they are not veins and have nothing to do with nerves. All the material is in a soft and flabby condition, and a section of the wing at this stage shows that it is folded backwards and forwards on itself like an 'accordion' pleated skirt, or a camera bellows (Fig. 34). The expansion is caused by fluid being forced between the membranes and probably also along the nervures, which, as already stated, are hollow. Now it will be easily understood that were there no other provision, the wing would merely swell out into a large bag, instead of the thin flat structure which is actually produced. Such a result is made impossible, however, by the presence of minute fibres extending from one membrane to the other, and preventing them from becoming widely separated. In a section of the pupal wing these fibres seem to be much longer than necessary for the purpose, but the peculiar nature of their action is such that whilst all other tissues expand, these fibres contract, and so rapid and complete is their shrinkage that in the fully developed wing they have almost disappeared. This contraction brings the upper and lower membranes of the wing so close together

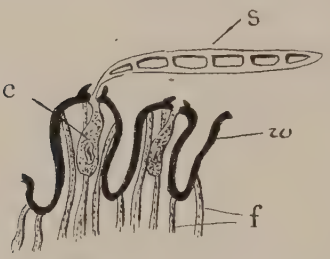

FIG. 34. Magnified view of a section of part of the developing wing inside a chrysalis. *w* is the membrane which will form the upper side of the wing. It is attached to the lower membrane (not shown) by the contractile fibres *f*. *c* is a cell forming the scale *s*, still in an imperfect state.

that the fluid which aided in their expansion is now forced out again, and though when fully expanded the wings are at first soft and useless, they rapidly harden and dry so that the insect can use them in flight. In those species which find themselves in the air as soon as they emerge, the expansion and drying of the wings takes place with great rapidity, but where moths hatch from the pupa underground, such immediate expansion would inevitably destroy the insect since it would be unable to make its way to the surface, or if it did its wings would be seriously damaged in the act. We therefore find, as already pointed out, that in these species the expansion is greatly delayed, in some cases for many hours.

Apart from the wings other great changes have occurred since the caterpillar days. The caterpillar is little more than a head and body. The butterfly, besides possessing four large wings, is seen to be divided into three main portions, the head, bearing the great compound eyes, the coiled proboscis, and the long antennae, the thorax which is the great muscular centre bearing the legs and wings, and the abdomen which contains the digestive and other organs.

The butterfly's head has little in common with that of its caterpillar. It has no jaws, but instead bears in the centre the proboscis or sucking organ, which when not in use lies coiled up like the hair-spring of a watch. On either side are two small jointed projections which seem to form a kind of case for the proboscis but undoubtedly have other and more important functions. These are called the palpi. The remainder of the head consists of the two great compound eyes, extremely elaborate and

important organs, formed of thousands of lenses and their attendant nervous mechanisms as described in the chapter on Senses. The caterpillar can do little more than distinguish light from darkness. The butterfly can see, and perhaps appreciate, the flowers, its mate, and the other attractions of its little world. In a very few butterflies and many moths there are also simple eyes or 'ocelli' on the top of the head, but as they are usually covered by the adjoining scales they can be of little use and are probably vestiges of some former condition, though they may still help the insect to the extent of distinguishing between light and shadow. Lastly, there arise from the head between the eyes the long characteristic antennae, the great complex sense organs of the insect. These are certainly the seat of its often very acute sense of smell, possibly also of hearing, in some cases, and there is little doubt that they govern its sense of equilibrium, since many butterflies when deprived of them are unable to control the direction of their flight. In some moths the head and thorax are elaborately ornamented with fan-like tufts of scales and hairs, and at Fig. 35 I have drawn a magnified front view of our beautiful Golden Plusia, a near relation of the well-known Gamma, or Silver Y moth. The illustration also serves to show the positions of the proboscis, eyes, and other organs.

The eyes are more fully described under the chapter on Senses. The next most prominent organs are the antennae, and these as special sense organs are undoubtedly of the greatest importance to the insect. In form they vary greatly, and at Fig. 36 I have drawn a number of examples taken from different species. The

antennae of butterflies are comparatively uniform in structure, consisting of a great number of joints, those at the extreme end being usually thicker than the rest, so

FIG. 35 Anterior part of the Golden Plusia moth much magnified, showing the elaborate ornamentation of fan-like plumes. The antennae and front legs are only partly shown.

that the organ appears clavate or club-shaped. Each joint is generally thickly scaled. The antenna is really a tube made up of small joints like a flexible pipe built from a series of rings. The surface is broken by a multitude of minute openings and pits in which are found

the extremities of delicate sense organs. These arise from a layer of nervous tissue communicating through branches with a great central nerve-cord. The latter runs through the whole length of the tube and is connected with the brain. There is in addition a supply of

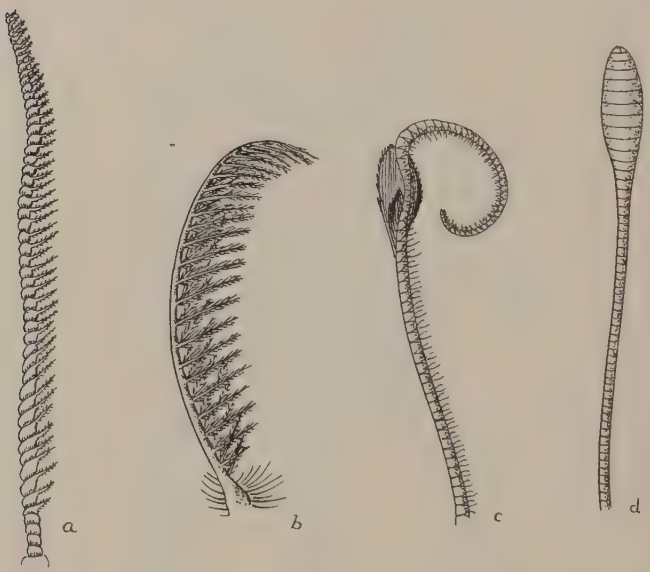

FIG. 36. Various forms of antennae. *a*, of the male Tiger moth ; *b*, of the male Gold-tail moth ; *c*, of an exotic moth (*Crymona rhetusalis*) ; *d* is a typical butterfly antenna with clubbed end.

air-tubes, or tracheae, as in all other parts of the creature's body. It is by no means easy to make out the structure of the sense organs in the antennae of butterflies. The outer substance is hard and often heavily pigmented, and the difficulty of cutting sufficiently thin sections is considerable. Four types of such organs may here be

described. In the first there is found, set in a cavity, a comparatively short projection which communicates with an elongated nerve-cell connected to the central nerve-cord. In the second form, long slender nerve-cells appear to communicate with delicate tubular hairs on the outer surface. The third consists of a stout projection with a small tooth-like point or points. The fourth is a long pointed bristle. The first and third of these are probably connected with the sense of smell, and the second and fourth with the sense of touch. At Fig. 37 are shown three types of these organs highly magnified. It should be borne in mind that the sense of touch may be used for purposes other than those with which we are ordinarily familiar, as for instance an appreciation of delicate changes in the air pressure when approaching solid objects. We have already said that a butterfly deprived of its antennae is unable to control its flight. This static function of the antennae is apparently internal and not dependent on contact with the outside air, since varnishing the antennae with shellac varnish does not in any way affect the insect's equilibrium. On

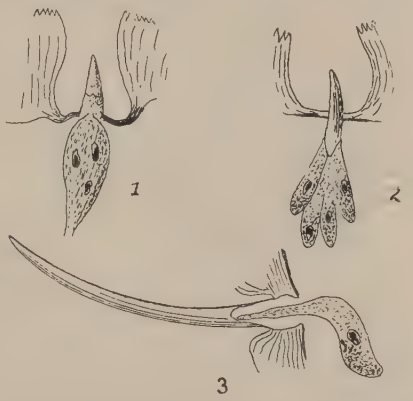

FIG. 37. Three types of organs found in the antennae of moths and butterflies. Nos. 1 and 2 are supposed to be organs of smell, and No. 3 an organ of touch. Note the large nerve-cells attached to each. (Magnified.)

either side of the coiled proboscis we find the organs already referred to as the palpi, which are soft pads usually heavily scaled and capable of considerable muscular movement. A section of one of these organs shows that the outer end is usually turned inwards, forming a deep pit, comparatively large inside but having a very small opening. Evidently it is important that solid objects should not gain access to this space since the opening is guarded by a great number of small projections all directed outwards. At the bottom of the pit are found numerous, rather thick hair-like structures, each arising from a nerve-cell, and all these cells form a layer connected with a large main nerve-cord (Fig. 38). The function of these minute organs cannot be tactile in the ordinary sense since they are protected from contact with external objects. Their meaning remains for the present obscure. In some moths the palpi attain enormous proportions and may be nearly as long as the whole body.

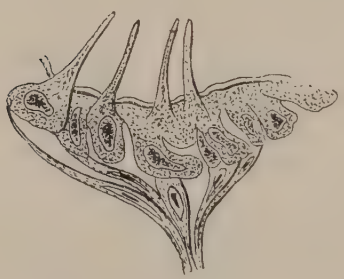

Fig. 38. Section through part of the palpus of a Tortoise-shell butterfly showing the peculiar organs of unknown function with their elaborate nerve connexions (magnified).

Lastly, let us examine the proboscis, which, as already stated, lies coiled up between the palpi. The organ is quite rudimentary in some moths, and it is certain that these do not feed in the perfect state and presumably have sufficient reserve material to provide for the continuance of

the species. The organ is, however, well developed in butterflies. At first sight it appears to be a simple slender tube, but its structure is really of a very complicated kind. It consists of two complete tubes which can be separated for cleaning purposes, but which are normally locked together by rows of tiny hooks. These two tubes are not themselves the passages through which the insect feeds, but each contains a trachea or air vessel, a nerve, and a great number of diagonal muscle bands the contraction of which causes the whole organ to roll up neatly in its accustomed fashion. The inner side of each of these tubes is concave, so that when they are locked together the two concavities form a third or central tube, through which the butterfly's liquid nourishment is taken, the sucking action being performed by a kind of bag or sac inside the head, provided with powerful muscles which enable it to contract and expand. At Fig. 39 I have drawn a diagram representing a section through the proboscis. At *t* is the tracheal or air vessel, *n* the nerve-cord, and *m* the muscles which cause the organ to roll up. The central tube, formed by

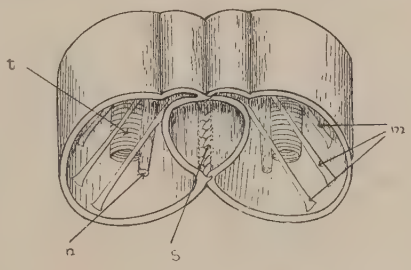

Fig. 39. Diagram of a magnified section through the proboscis of a Purple Emperor butterfly. The central tube, *s*, is the real sucking tube, and the whole organ can be separated into two for cleaning, by the unlocking of the hooks seen on the central line. The two side tubes each contain an air vessel, *t*; a nerve, *n*; and diagonal muscle bands, *m*.

the interlocking of the two halves, is shown at *s*. This passage is very small and its liability to become obstructed by the smallest particle of solid matter necessitates the ingenious provision by which it can be laid open and cleaned throughout its entire length. Exactly how the insect performs this doubtless frequently necessary operation I have not yet been able accurately to observe, but probably the palpi, and possibly the feet, are

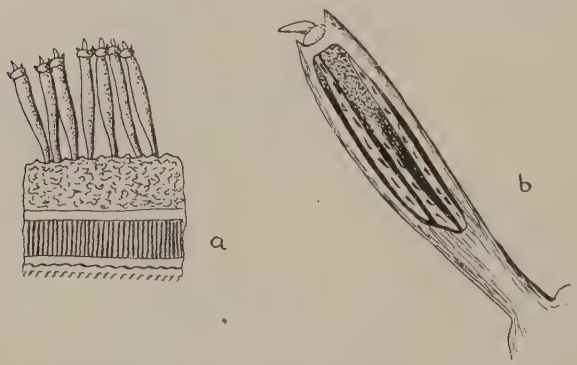

FIG. 40. *a*, part of the end of the proboscis of the Purple Emperor with the taste organs on upper side of figure; *b*, one of the taste organs still more magnified and cut open on the side to show the three delicate nerves within.

brought into use. At the extremity of the proboscis there is a series of projecting papillae, mentioned also under the chapter on Senses. At Fig. 40 *b* is an enlarged view of a single papilla with one side partly cut away to show the three delicate nerve fibres within. Each papilla ends in two points between which is a button-like structure provided with a central projection. I am not aware that any successful experiments have been carried out in order to test a butterfly's discrimination

in the matter of taste. It is not easy to induce a butterfly to feed in voluntary captivity.

The thorax, as I have said, is the muscular centre of the body, and to it are attached the legs used for alighting and walking, and also the wings. Butterflies and moths, like other mature insects, have six legs. A careful observer will, however, note that certain butterflies, as for instance the Peacock, Red Admiral, Tortoise-shell, and others, only use four legs for alighting and walking. This is because in many butterflies the two front legs are much reduced in length and normally lie tucked up close to the body. All our British butterflies except the Swallow-tail, the Whites, and the Skippers have the front legs more or less reduced or modified in one or both sexes; and it is curious that the extent of the modification is different in the two sexes. The fully developed leg ends in a series of five joints which together form what is known as the 'tarsus'. The last joint is of much more complicated structure than the rest, and is seen at Fig. 41, which is a drawing of this structure in the small Cabbage White butterfly. There are two well developed double claws which enable the insect to grasp its support, and between these a centrally placed projecting pad called the pulvillus. The precise function of this organ is doubtful, but it is probably connected with the sense of touch. Closely adjacent to each claw is a brush-like organ, the 'paronychium', the function of which may be to clean the claws and pulvillus

Fig. 41. The foot of a Cabbage butterfly showing the claws and other appendages (magnified).

and other parts of the creature's body. In the Cabbage butterfly and its relations all the six feet are thus elaborated. If, however, we examine the front feet of a Tortoise-shell butterfly we shall find a much simpler structure. If it be a female all the five joints of the tarsus are reduced in length, much degenerated, and the claws mere rudiments. At the joints there arise short stiff spines. The presence of the spines and the persistence of the joints, though in a reduced form, suggests that a new use has been found for the short front leg, and the matter is still the subject of investigation (see note, p. 30). Should the specimen examined happen to be a male, it will be found that almost all trace of the five joints has disappeared, and the tarsus consists merely of a short joint densely clothed with hairs and having the appearance of a small brush.

The structure of the fore feet is of great help in distinguishing the sexes, because with a little practice the differences can easily be detected with the help of a pocket lens or even with the unaided eye. All the known butterflies have been divided into definite groups called families; this general classification is made largely on the structure of the feet, whilst the more minute classification is based mainly on the arrangement of the nervures or stiffening rods in the wings.

The movements of the wings are brought about in a peculiar and unexpected manner. They are not moved by the direct action of muscles attached to them, or only very slightly so, but are controlled by the rapid expansion and contraction of the thorax itself. This movement of the thorax is caused by the great elevator and depressor muscles attached to its inner surface, and

the changes in shape of the thorax bring about the raising and lowering of the wings. It may here be mentioned that this indirect muscular action in the flight of insects is by far the most usual. In Locusts and most of their relations the direct and indirect muscles are about equally developed; but in the dragon-flies, as might be expected from their wonderful powers of flight, there is a great development of direct wing muscles. In these insects there are no less than five depressor muscles, three elevator muscles, and one adductor muscle, all acting directly on the wing. In many moths the upper and lower wings are fastened together by a spine or spines called the 'frenulum' attached to the hind wing and engaging with a groove or fold in the fore wing.

The internal organs of the butterfly consist firstly of a nervous system which includes a somewhat complicated brain in the head. From this extend two nerve-cords running along the lower internal surface of the body to the posterior end. In nearly every segment of the body this central nerve-cord is swollen into subsidiary brains called ganglia, and though there is necessarily a certain degree of co-ordination in the whole system, nevertheless the greater part of the nervous mechanism of each segment is controlled by the ganglion situated in that segment. The same system is common to all insects and has this effect, that the loss of any part of the body inconveniences the creature only to the extent of the relationship of the lost part to the whole. Thus a wasp deprived of its abdomen will swallow honey or syrup which collects in a bead where the stomach once was, and if a bit of cork or pith of about the shape and

weight of the lost body be attached to the thorax the insect may fly away. A butterfly deprived of its head cannot fly because sight, equilibrium, and directive sense are gone, but it behaves merely as though it were in the dark, and can still use its legs and flap its wings. The sense of pain as we know it is probably little developed in the butterfly and in other insects. Its tactile sense causes it to avoid unfamiliar contacts and to struggle against forcible detention, but that it can be hurt in the ordinary meaning of the word is extremely improbable. A butterfly's antennae may be snipped off without its betraying, even by a movement, any consciousness of the injury. I record these facts not in any way as an excuse for what thoughtless persons would term cruelties. The true naturalist loves his subjects and never maims or destroys in a wanton spirit. Incredible as it may seem, I still meet persons who believe that the entomologist transfixes his specimens alive and allows them to die a lingering death. That they should all die at the same height on the pin and with their wings, legs, and antennae all neatly arranged at the same angles, doubtless appears to such people as but another example of the proverbial success which rewards unrighteous dealing.

The circulatory or blood system of a butterfly is of a very simple character. Lying along the back, above the other organs, there is a vessel which acts as a heart. It is in the form of a tube, open at each end and having valves in the sides which open inwards. The blood is free in the whole cavity of the body, but by the pulsation of the heart it enters the valves and is forced forwards and emerges near the head.

Breathing is effected by a complicated system of air-tubes which begin at the 'spiracles', small openings in the sides of the body, and branching from thence convey air to every part of it. The fineness of the ultimate branches of this system may be judged from the fact that in the Tortoise-shell butterfly there are at least forty thousand such tubes in each eye.

The digestive canal is a simple tube into which two salivary glands open in the head. In the abdomen there is a large bag-like structure or reservoir, opening into the oesophagus close to the junction of the latter with the stomach. At the posterior end of the stomach there are attached two tubes, each of which divides again into two, forming four delicate vessels of comparatively great length and reaching in their many turns and convolutions to nearly every part of the body. These are known as the Malpighian tubes and are the excretory organs, having a function similar to that of the kidneys in vertebrate animals. The remainder of the body cavity is occupied by the reproductive organs, the muscles, and a large number of fat cells.

Other details of butterfly structure are described in the chapter on Scents.

VII

SENSES

CAN a butterfly hear, feel, taste, smell, and see? Has it (we might also ask) any other senses, unknown to us? The latter question is the more difficult, since our ideas are all so firmly bound up with our own experiences that it is to some extent beyond our powers to conceive of a sense we do not ourselves possess. Nor are the replies to the first question so simple as may at first sight appear. Our senses are intimately associated with the state we call consciousness, and it would be fair to inquire whether an insect with its complicated repertoire of so-called instinctive actions is, in any sense that we can understand, a conscious organism at all. Nevertheless, I think we may fairly assume that however inconceivable it may be to our limited imagination, some infinitesimal ray of consciousness must be allowed to creatures so highly organized. We must be careful not to strain the point. We ourselves might say, 'I smell honey, it seems to be over there, I will walk to the place and get it'. All this implies thought followed by purposeful action. On the other hand our butterfly may 'smell' honey, and fly to the place, and feast upon it, merely because that particular scent acts as a stimulus and causes it to move in the direction unconsciously suggested. Nevertheless, the manner in which the senses act on the creature need not complicate our inquiry into the existence of the senses themselves.

Evidence that butterflies and moths have a sense of hearing is extremely difficult to obtain. That an insect 'takes no notice' of sounds is no evidence that it is deaf. We ourselves have a fixed range of hearing: the vibrations in the air which stimulate our auditory nerves must be of a certain rapidity before we hear them at all. If that rapidity be increased we can still hear the sound up to a certain point, but when the vibrations exceed a certain number per second we are no longer conscious of their existence. The squeak of a bat is what we call a very high note, indeed it is at the limit of human hearing and many people are unable to hear it at all. The range of hearing in vertebrates is comparatively wide, but if we can suppose conditions under which it would be unnecessary for any purpose of our life to hear more than a few sounds of nearly the same pitch, and further imagine ourselves capable only of detecting sounds of such limited range, we shall arrive more nearly at the conditions which seem to exist in those insects which appear to possess hearing powers.

The antennae of certain male mosquitoes have an elaborate system of delicate hairs, which, though unaffected by the majority of notes, vibrate when a certain pitch is reached, and the note which causes the maximum vibration is that given out by the female mosquito when flying. Thus it may be said that this mosquito can hear its mate, but whether its powers extend much further seems doubtful. In inquiring into an insect's powers of hearing it is natural to ask whether the insects themselves make any noises, necessary and essential for others of their own species to hear, and we are at once reminded of the grasshopper, the cricket, and others whose cries

are so familiar. To what purpose the grasshopper's crying aloud of his wooing, 'Sole voice that 's heard amidst the lazy noon,' if his mate cannot hear the serenade? The grasshopper certainly has ears, or at any rate elaborate organs which appear to fulfil that purpose, and curiously enough they are situated in its legs. We may apply the same inquiry to our butterflies. Do any of them make a noise, audible to us, which can be supposed to have any connexion with courtship? The reply is that such noises are very rare though they do occur.

In South America there is a butterfly of a pale grey colour with many darker grey spots (*Ageronia*). When flying or moving its wings it can produce a clicking sound. Sir George Hampson long ago described the peculiar apparatus by which the noise is made. It consists of a kind of hook or projection on the fore-wing which engages with a double hook on the body. The noise is especially noticeable when two or more of these butterflies are fluttering round each other in the air. There is a beautiful little green moth in our own country, the Green Silver Lines, which makes a very audible sound under similar circumstances, whilst a grey, black, and yellow butterfly in Africa makes a noise 'like peas in a box'. Certain male Indian and African moths of the genus *Aegocera* have, on the front wing, a patch of scaleless membrane; and by scratching (so it would appear) the membrane with large spines which are developed on the fore feet a noise is produced. In the same way the 'Whistling moth' of Australia belonging to the genus *Hecatesia* has in the male a large area of the wing quite devoid of scales and of a corrugated structure (see Fig. 42). The fore feet have also special spines. Such cases are amongst

the very few which furnish evidence that these insects have a sense of hearing, since in these 'whistling moths' the apparatus is peculiar to the male, and hence we may assume that the female has the power of hearing it. Indeed, the sound-producing organs are so highly developed that no other conclusion is possible.

Our own 'Death's Head' moth can squeak, which it does by drawing in and expelling air through the proboscis, though this accomplishment is probably used to startle enemies, rather than for love-making. Now although a definite sense of hearing is difficult to detect in these insects, nevertheless it is a fact that the majority of moths possess a very elaborate paired organ, sometimes in the first segment of the abdomen, sometimes in the thorax, which has all the appearance of a complicated and effective ear.

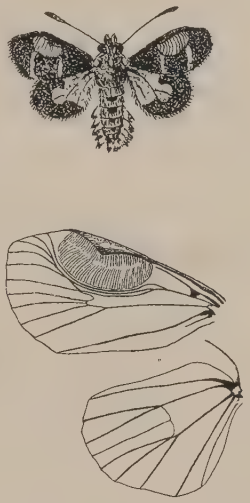

FIG. 42. The Australian Whistling moth (*Hecatesia fenestrata*). The lower figure was drawn by Mr. Tams, and is a magnified view of the wings with the scales removed, and showing the 'drum' in the fore-wing.

If any of our common Geometers, such as the Brimstone moth for instance, be carefully examined, it will be seen that there is on each side of the body, just behind its junction with the thorax, a rather conspicuous opening. Externally no more can be seen, but careful dissection shows that each of these openings leads into

a comparatively large cavity lined with a rather stiff layer of chitin, already mentioned on p. 91. This cavity is very like a kettledrum in shape, but the 'kettle' part of it has a hole in one side, and this is the hole we see in the side of the insect. The head or drum part of the kettledrum is a membrane of excessive delicacy which may be thought of as the tympanum or skin of the drum on the inner and forward side of the organ. Its under side is exposed to the air through the hole in the insect's body. Its upper side, which is thus inside the body, has lying across it, but not touching it, a curved bar, one end of which grows out of the hard substance of the body of the drum, and the other is attached to the edge of the skin or tympanum by muscles and probably by nerve connexions. From the curved bar to the centre of the tympanum there is a delicate nerve whose function must be to detect the vibrations of the drum. At Fig. 43 I have endeavoured to show the position and structure of

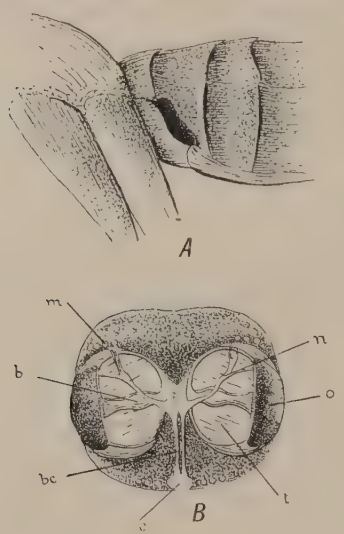

FIG. 43. *A*, magnified view of part of the body of one of the common 'Carpet' moths showing the opening in the side. *B*, the tympanic organ dissected out; *o*, the openings; *n*, labyrinth of nerve and connective tissue; *b*, the curved bar which protects the diaphragm, *t*; *m*, the cut ends of muscles; *c*, the central nerve-cord; *bc*, the connexions from the central cord to the labyrinth.

this peculiar organ. It is generally found in both sexes of the moths in which it occurs, and it is not found in any butterflies so far as is at present known. Unless it is the seat of some sense which we do not ourselves possess, then it is undoubtedly an ear of a highly developed kind. Its comparatively great size shows it to be of the first importance to the insects possessing it, but its true function is still being investigated. Therefore we can only say at present that many moths have well developed organs which have all the appearance of ears, though their precise function is not yet certainly proved.

As to the sense of taste we may at least assume that our butterflies can distinguish different kinds of food. Even in ourselves taste is a very limited sense. It is supplemented in many ways by the sense of smell, and all the delicate shades of difference which we call flavours are really distinguished by smell. At the end of the butterfly's long coiled proboscis are tiny projections or papillae, and these are considered to be organs of taste (see p. 100). Minnich has, however, shown that some butterflies appear to have taste organs in their feet.

The sense of touch is very easily tested, and there can be no doubt that active butterflies and moths are very sensitive to tactile impressions, although certain parts of the body are more sensitive than others.

When at rest, at times when they do not habitually fly, they may often be touched without giving any noticeable response. This, however, is no proof that they do not feel the contact. Many, as we shall see, are very inconspicuous when at rest, and to maintain a deception which may mean safety it is necessary for them to remain passive when touched. Caterpillars are extremely sensi-

tive to touch and readily detect contact with any part of the body, though many of those which resemble twigs and other inanimate objects persist in their immobility even when handled.

The hairs on the bodies of both caterpillars and butterflies afford no doubt a highly sensitive medium for detecting contact. Butterflies and moths often lay their eggs with great care and sometimes with wonderful regularity of arrangement, and this operation is probably performed by a delicate tactile sense, since the insect, even if the operation is carried out in daylight, cannot see its own egg-laying.

Butterflies readily distinguish familiar and unfamiliar contacts, as my friend Professor Poulton pointed out long ago. A butterfly on a flower, if touched with the finger, will take flight in alarm, but can be stroked with a grass stem or other familiar object without apparently taking much notice of the intrusion. It is when we come to the sense of smell in insects that we find a development which often passes comprehension. To a human being devoid of any particular sense, the real meaning of the exercise of that faculty must always remain something of a mystery. Thus a man devoid of what we understand by the sense of smell can have little idea of the scents of flowers and the delicate flavours of fruits or other eatables. But even those who have this sense most highly developed, measuring by human standards, can have no conception of such an olfactory sense as is possessed by certain moths. Indeed, so wonderful in some instances is the exercise of this power, that many observers have been tempted to regard its manifestations as evidence of a sixth sense entirely unknown to us. Those who have read the late

Henri Fabre's description of the assembling of the great Peacock moth, and of the Oak Egger, will not require to be told that many moths have the power of finding, apparently by scent, the females of their own species. We do not know the limit of distance over which this power can be exerted, though it would seem that something might be learnt by experiment.

If a female Oak Egger moth be placed in any sort of a cage which is not air-tight, male moths of the same species, if there are any in the neighbourhood, will assemble in great numbers and endeavour to reach her. This is true even in localities where the moths are rarely seen at any other time. Fabre had never seen the Oak Egger in his locality, and apparently the great Peacock moth was extremely rare. By chance he obtained a pupa of the Egger moth which produced a female, and for several days the room was invaded by great numbers of males. His female Peacock moth attracted nightly invasions of the males, which came into various parts of the house, but in greater numbers into the room (frequently changed) where the female was imprisoned. As this moth measures some six inches or more across the wings the sight must have been impressive.

Many years ago the writer placed a female Peppered moth, in a pill-box covered with muslin, on the table in a room, and left the window open at the top about twelve inches. In the course of an hour or so some seven males found their way into the room, and this in spite of an atmosphere of tobacco smoke. A box which has contained the moth, or a twig on which it has rested, will prove quite as attractive for a time. It is said that the Kentish Glory moth will settle on the clothes of a person

carrying a female in his pocket. Many more examples could be quoted, but these must suffice.

The power possessed by these moths is attributed to their sense of smell. There is no other sense of which we have any knowledge which can explain it. The theory is supported by the fact that the female is not perceived if she be enclosed in a tin or other more or less air-tight receptacle. And that a box or other resting-place which has lately contained her may be equally attractive, suggests beyond a doubt that there is some material emanation which can be perceived by her would-be suitors. The presence of other smells does not seem to affect this sense in moths, and I am therefore inclined to suppose that their olfactory powers are specialized, and that they perceive only the particular odours which are vital to their being, those, that is, which suggest food or a mate, and in addition they doubtless select, at least partly, by scent, the correct food-plant on which to deposit their eggs. The perception of odours may be regarded as a chemical action. Infinitely minute particles of the substance, probably in the form of a gas, permeate the air, and coming into contact with the sense organ, produce an effect recorded by the brain, which can distinguish between the stimuli of different substances. Fabre confessed himself unable, in spite of all the evidence, to believe that the assembling of moths could be due to their perceiving at great distances the scent of the female. 'As well might one expect to tint a lake with a drop of carmine' as suppose the scent of the female to affect the atmosphere to such great distances. But that great observer failed to remember that the scent in question is not perceptible to our senses. We have therefore no means

of gauging its real strength. I have already referred to the inability of some otherwise normal persons to hear notes of a very high pitch, such as the squeak of a bat. A fly walking about in a match-box does not make a very great disturbance, but with the assistance of an apparatus called a microphone, which magnifies sound, it can be made to resemble a hailstorm on a glass roof. Given then that the moth does produce particles capable of being carried by the air, and of affecting certain sense organs which happen to lie in their path, our remaining difficulty would seem to be that of supposing these particles to be sufficiently numerous to taint so large a bulk of air as may lie between the moth and its mate.

But is the difficulty so great, after all? Our own senses are susceptible to the odour of musk. An extremely small quantity of this substance will scent a room for long periods of time, without suffering any appreciable loss in weight. If so small a quantity of material can make the presence of its particles felt in the circulating air of a room for months and years, there seems no great difficulty in supposing that the moth's scent, probably infinitely more volatile, can, for a short time, fill the air for hundreds of yards or even for miles around. The error seems to lie in the idea that because we cannot perceive the scent it must of necessity be very weak, whereas it may be, and doubtless is, extremely strong. What strength of colour has a scarlet begonia to a person who is red blind?

Compared with many moths, butterflies have the sense of smell less remarkably developed. At least they do not appear to find their mates entirely by this faculty. Being day-flying creatures they rely to a greater extent on

sight, though they certainly find their food to some extent by smell. Such a fact will be appreciated by those who have seen the beautiful Red Admiral swarming down to over-ripe plums, or the great assembly of all the butterflies in the garden on the honey-scented Buddleia. Nevertheless, the butterfly trusts a good deal to sight for finding flowers, although, as we shall discover, it cannot see very far.

The question now arises, where is the seat of this remarkable sense? All experiment goes to show that it lies in the antennae. There are certain flies, such as the 'Bluebottles', which will search out from great distances any scrap of decayed meat or other (to us) ill-smelling substance. If deprived of their antennae such insects at once lose interest in the exciting material. The moths which I have described as detecting by scent the presence of their females, lose the power if the antennae be removed, though as Fabre has shown they do not appear to notice the operation of removal. With butterflies it is a very difficult matter to make any experiments with the antennae since it would appear that these organs are not solely concerned with scent. In the writer's opinion they certainly serve the purpose of organs of equilibrium, and also afford a sense of direction, since a butterfly deprived of its antennae flies aimlessly,

> As though escaped from Nature's hand
> Ere perfect quite—

and generally straight up into the air. If we examine the antennae with the microscope we find that they possess several different kinds of minute organs, and these doubtless act in different ways, so that we cannot interfere with one sense without disturbing another.

The males of certain moths, especially those which

show such remarkable powers of finding the female, have antennae of a highly complicated kind, whereas the female antennae are of quite simple structure, and it has been found that in the Vapourer moth the particular type of minute organs which are considered as belonging to the sense of smell are eight times more numerous in the male than in the female. If then we decide that the sense is controlled by these antennal organs, and if we remember that the antennae are comparatively long, projecting, and movable at the will of the insect, we shall begin to understand a little better something of what such a sense may mean. Our own olfactory organs, feeble as they are, are rendered still less useful by being internal and immovable. Moreover, they are not situated in two separate series, each of which can be moved about in all directions and independently of the other. But a butterfly's antennae have their sensitive cells outside of, and away from, the body, and each can be moved in any direction. Add to this the extreme delicacy of their action, and we can realize the full force of Forel's contention that such an apparatus constitutes an olfactory organ 'turned inside out', and that the sensations thence derived may give the insects ideas of space and direction which make their power of smell almost a sixth sense, difficult for us to imagine or describe.

There remains one other sense, that of sight, and it is when we come to examine a butterfly's eye that we begin to realize how complicated a structure may be concealed in what is to us a trifling space. It would be impossible to convey to the general reader an adequate idea of the peculiarities of the insect eye without first explaining something of the action of our own eyes. Fortunately photography is an almost universal amusement, hence

there are few who have not some practical experience of the action of a lens. We know that a lens collects the rays of light reflected from the objects in front of it, and projects them, in their relative position, on to the sensitized plate at the back of the camera, where they form a little replica of the objects which the lens 'sees'. The image formed inside the camera is upside down and the wrong way round, as we know when we look at the focusing screen. A lens acting as does that of a camera always produces this kind of inverted image, and of course it does not matter, as it is readjusted in printing the photograph. Now the human eye contains a lens, not of course of glass, but acting in a similar way. The analogy of the camera is still further paralleled in the action of the pupil of the eye, which opens or closes to regulate the amount of light, just as we open or close the diaphragm of our camera lens. The image produced by the lens of our eye is thrown on to a complicated nervous mechanism called the retina, whence it is communicated to the brain, which immediately responds to and interprets it. Moreover, the image on the retina is also upside down. We are not conscious of this fact because lifelong experience enables the brain to interpret the image correctly. Furthermore, we receive two images, one from each eye, and they are not quite the same, because the left eye can see farther to the left than can the right. The brain interprets the two images as one, but nevertheless utilizes the slight differences to judge distance, in fact it is in this way that we get well-known stereoscopic effect of distance. We can reproduce this in a photograph by taking two pictures with two lenses and looking at the result through a stereoscope, when it appears to be solid. So much then for the action of our own eyes

which are essentially similar to those of other mammals, and of the birds, reptiles, and fishes.

When, however, we come to the eye of an insect we find that nature in a wanton mood has evolved an apparatus of infinitely greater complexity, but of probably inferior performance. The butterfly's eyes are fixed and immovable. They cannot be turned towards an object nor can they be opened or closed. Only the movement of the whole insect, or at least of its head, can alter the position of the eye in relation to its surroundings. Our eyes are provided with an arrangement of muscles which automatically alter the focus of the lens, according to the distance of the object we wish to see. The butterfly's eye does not focus itself, and for that reason, amongst others, its performance is perhaps inferior. It is not easy to explain the real action of the butterfly's eye, but so wonderful in its complication is this organ, that those who have the patience to read what follows should be repaid by the interest it affords. Examine Fig. 44. At *l* is a lens, and we will suppose two rays of

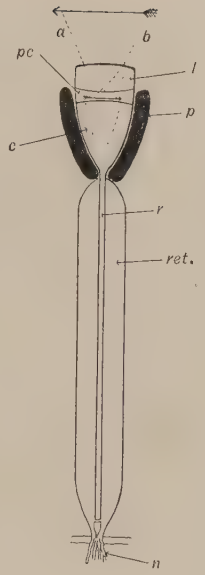

Fig. 44. Diagram of a single element of the butterfly eye. *l*, the lens; *pc*, a layer of transparent medium between this and the secondary lens or cone, *c*; *p*, the pigment cells which surround the cone; *r*, the transparent rod on which the cone rests; *ret.*, the nerve-cells, of which there are eight, surrounding the transparent rod; *n*, the nerve fibres proceeding to the brain. (The diagram is not in strict proportion, the part marked *ret.* should really be about three times the length shown.)

light, *a*, *b*, from the little arrow, to pass into it. Now it is the property of a lens to bend rays of light towards its thickest part. The result of this process is that the rays cross each other inside the lens and come out at the other side reversed. Hence beneath the lens we get a little inverted image of the object, represented in this case by the smaller arrow. Obviously beyond this point, if nothing intervened to prevent it, the rays would separate farther and farther and be scattered and lost. But below the lens, *l*, is another lens-like body called the cone, *c*. The action of this cone is to twist the rays round again, so that if we could see the image at the point of the cone, we should find it once more the right way round. It will in fact have become what is known as an erect image.[1] Now here arises an effect which is one of the most remarkable features of this apparatus, and which is due to the peculiar optical action of the cone. We have seen that the rays, after passing through the first lens and forming an inverted image, are travelling away from each other, and if not readjusted by the cone would be scattered. We might therefore suppose that the erect image formed by the cone would only be found at its point, after which the rays would be scattered again. But this is not so. The rays do not leave the cone

[1] It is true that in the eyes of some other insects the cone does not reinvert the image, *hence as an image* it is of no value. Curiously enough, the eyes of the dragon-fly, which has the best sight of any insect, are of this form. The explanation is that the enormously greater number of lenses in the dragon-fly eye more than make up for the deficiency. Each lens throws, not a clear image, but a dot of light of the average value of that of its field of view. All these together make up a good general image on the same principle that a half-tone illustration (like those seen in newspapers) is made up of a great number of light and dark dots of varying intensity.

pointing away from each other, but perfectly parallel, and hence they pass unaltered right down the transparent rod *r*, all arranged in their proper order. Hence, if we pack round this transparent rod a set of sensitive nerve-cells, *ret.*, we can imagine the rays of light stimulating these nerves so that each records its own little part of the picture viewed by the lens *l*. If the reader has succeeded in following the description of this rather complicated action he will be able to understand that such a combination of lenses and nerves forms an apparatus capable of recording the view of the external world comprehended by the lens *l*. Now let him ask himself what such a view would be likely to include. The lens is small, so small that over a thousand in a row would barely measure an inch. The field of view will, then, be exceedingly limited, even more so than might be expected, since only the rays of light which enter the lens centrally, or nearly so, can help to form the image.

Those which strike the lens at any appreciable angle are caught by the black substance *p* which surrounds the cone, and are absorbed by it. Hence, if our butterfly's eye consisted merely of one such piece of apparatus, it would get a very restricted view and in one direction only. Now although this one apparatus is far more elaborate in its lens action than the human eye, nature is regardless of such complications. The difficulty is surmounted in a prodigal fashion, by providing about five to six thousand of these structures, which, placed side by side in the form of nearly a hemisphere, and pointing in many directions, together form one eye of the butterfly. Each element records its own little part of the view, and all the parts together form a comprehensive

picture, just as five thousand little toy blocks might be put together to form a large complete design.

Now note the value of the cone *c*. Our own eyes form an inverted picture, but it is *all inverted at once*, and therefore correct, although upside down. But if each of the elements of the butterfly eye gave a *separate* inverted picture, hopeless confusion would result, since each little part of it would be independently reversed. Such is the action of this beautiful though probably rather imperfect organ. Nearly all insects have eyes of this type, though all do not act in precisely the same manner. For its size the butterfly's eye is, at close quarters, perhaps the most efficient type of the compound eye, and yet the insect is very short-sighted and probably unable to recognize even another of its own kind at a distance of more than three or four feet. We cannot enter here into the action of other insect eyes which are not quite the same, but one well-known peculiarity must not be passed over. Who has not drawn aside the blind of a lighted room and seen a moth, probably a 'white ermine', sitting on the outside of the window pane, its furry head illuminated by two flaming rubies, its eyes, the fire in which rapidly fades away? Do its eyes really give out a light of their own? To understand the cause of the light we must return to the black structure *p* in Fig. 44. In the butterfly's eye this black sleeve round the cone does not move. The insect is fitted to fly in bright sunshine, and if that fails the creature can see but little and generally ceases to fly at all. But in the moth's eye the black sleeve can be contracted so as to move forwards and expose a larger area of the back of the cone. When this happens, more light is passed through the

cone, since the rays entering the lens at an angle are no longer absorbed by the dark pigment. When a moth is in the dark, the black sleeve is drawn forward so that the greatest possible amount of light may enter the eye through the cone. When we pull aside the window blind the light from the room not only enters the eye, but is reflected back again from its inner layers and so causes the moth's eyes to shine. The strong light, however, induces the black sleeves to move backwards over the cones, and not only allows less light to enter the eye, but also interferes with its reflection. Hence the fiery glow fades and disappears. The movement of this pigment is in fact similar in its purpose and effect to the opening and closing of the pupils of our own eyes, a movement which can readily be seen by closing one's eyes for a while and suddenly opening them in a strong light in front of a mirror. Fig. 45 is a diagram of part of a section of a butterfly's eye showing several of the lens and nerve elements composing it. Actually each lens with its cone rests on a column of eight nerves surrounding the central transparent rod. Each nerve in the eye of a Tortoise-shell butterfly has a delicate air-tube attached to it, so that each whole eye has about forty thousand nerves and a similar number of air-tubes.

Does a butterfly see all the beautiful colours of the flowers it visits, and those of its mate? So inevitably is the creature associated with colour that it seems at first unnecessary to ask such a question. And yet at least one observer has set forth at great length his opinion that all insects are colour-blind. How are we to investigate such a matter? We must first consider what is the nature of colour. It is not a substance, in fact it has no

material existence at all, and what we call 'red' is merely a name for a sensation which 'red' things give us when we see them. How can we tell whether a red flower produces the same sensation in a butterfly? The reply

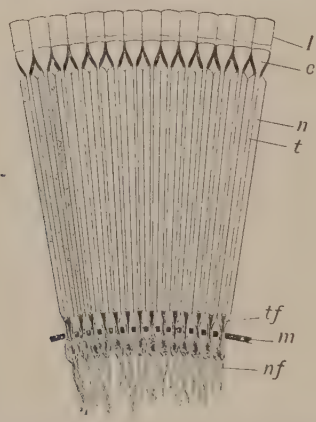

FIG. 45. Diagram of part of a section through a butterfly's eye to show how the elements are arranged. *l*, the outer lenses; *c*, the secondary lenses or cones; *n*, the nerves; *t*, the transparent rods; *tf*, the tracheal funnels, one at the base of each transparent rod. Each tracheal funnel communicates with the general air system of the insect, and gives off eight delicate air-tubes to the nerves which surround it. *m* is a membrane separating the eye proper from the brain cavity. The eye nerves become slender threads at this membrane and pass through minute holes therein. *nf*, the nerve fibres (not all shown), which are here clustered round large cells, and pass thence to the brain.

is simple, we cannot do so. Though we are fairly safe in assuming the probability, we do not in fact know whether the sensation we call red is exactly the same sensation even in two individuals of our own species. Evidently we must approach the subject from a different

point of view, and seek to know more of the nature of colour apart from our names for its sensations.

All colour is dependent on light, and though our ideas as to the nature of light itself are at the moment the subject of some reconsideration, it may be safe to say that light is of several kinds. That which reaches us from the sun is made up of a mixture of all these different kinds, and when they all strike our eyes at once we say it is white. There are various ways of filtering white light so that some of its ingredients will pass to our eyes and others be stopped before they reach us. A piece of pure blue glass is such a filter. Only the sort of light we call blue can pass through it. It is transparent to blue light, but as opaque as a block of wood to red, green, yellow, or any other sort of light. But the light we are considering may not be passing right through anything, it may be reflected from the surface layers of a substance. This is the effect with which we are most familiar. A 'yellow' flower is one which absorbs all the light falling on it except just that mixture which gives us the sensation we call yellow; this it is unable to absorb, and so reflects it back to us and we say the flower is yellow. Flowers have no 'colour' in the dark, and this is so not because we cannot see them but because there is no light for them either to absorb or reflect. These facts can be more easily appreciated by looking at a pure red flower, such as a pelargonium, through a piece of pure green glass. The flower is 'red' because it reflects only that kind of light which gives us the sensation we call red. But pure green glass cannot pass that kind of light. It stops it as a filter would stop sand. Hence the red light reflected by the flower cannot

reach our eye through the green glass. Thus the eye receives no light at all from the flower, and what is the result? It appears to be perfectly *black*.

Perhaps now, we can realize something more of the meaning of colour; and with our new knowledge we can put our first question in a better way. Can butterflies distinguish those differences in light which produce in us the sensations we call colour? If they can do so the faculty is not merely the same as detecting differences in *brightness*. An ordinary photograph reproduces differences of brightness, but all in shades of one colour, namely that of the substance used for making the print. Indeed, a totally colour-blind creature with otherwise good sight would see the world as in an uncoloured photograph. It is impossible without entering into highly technical arguments to describe fully the experiments carried out by the writer and others to test this faculty in butterflies. Some attempt may, however, be made to indicate the various lines on which such investigations were conducted. In human vision colour-blindness varies greatly in extent and in the particular colours affected. It may, however, be stated that if there is any colour-blindness at all, red is generally the first sensation to be lost. If then a person blind to red were to be given red spectacles, since only red rays could pass through such spectacles our red-blind person would be unable to see anything at all.

How (the question arose) might a butterfly be fitted with red spectacles? Such an experiment is not so difficult as might at first sight appear. The outer surface of the insect's eye with its thousands of minute lenses is hard and horny and not easily injured. A transparent

red dye was obtained and carefully painted on to this surface so that none but red rays could enter. The butterflies were then liberated after having been marked in such a way as to be recognizable. Now had they been red-blind they would, in the circumstances, have been totally blind, but on the contrary they were still able to see and alight on flowers. This experiment was first carried out with our common Tortoise-shell butterfly, in the pattern of whose wings red is largely represented. The experiment showed that the insect is certainly not red-blind, and indeed we should hardly expect it to be blind to the colour of its own mate. The same experiment was carried out with the common Large Cabbage butterfly, and it was found that the insect was much confused by its red spectacles and flew about aimlessly. Evidently it was at least partly red-blind, and we recall at once the fact that it has itself no red colour, and the ability to appreciate red rays would not be of great service to it. It is noticeable also that it rarely visits red flowers.

A more elaborate and more convincing experiment was conducted with a bed of asters of various shades of purple, pink, and white as part of the apparatus. It was found that the purple asters were selected by the butterflies in preference to the others; evidently the purple against its green background was more conspicuous to the passing insect than the other colours. This colour is also very conspicuous to our own eye, not because of its *brilliancy*, but because of its *colour*. A series of photographs of the asters were taken. A photograph taken through what is called a compensating screen, which gave a result representing the relative luminosity of the colours, showed that the purple aster was less

luminous than the others and incidentally confirmed the view that it was conspicuous principally on account of its *colour*. Other photographs were taken through various screens which allowed only certain colours to pass, so that the plates were rendered blind to different sets of rays. In all these the purple asters were still less conspicuous than in that photograph which represented the action of all the rays at once. It may thus be concluded that the butterflies, mostly Small Tortoise-shells, which found the purple asters more conspicuous than the rest, must be sensitive to all the rays, and that the greater ease with which the asters were seen was due, not to their luminosity, which is poor, but to their colour, which is rich, and that therefore our insects are by no means colour-blind.[1] In other experiments certain butterflies were found to examine with care dead and dried specimens of their own kind or even paper models, provided they were correctly coloured, whilst they ignored such artifices when incorrectly dyed.

We can understand that different species of butterflies and moths are likely to present great variation in such a faculty as this. Nature rarely wastes upon her children powers for which they can have no use, and we should not expect to find a delicate colour-sense in a moth which flies only at night.

Our butterflies have then senses similar to our own. Hearing is probably present in most moths; taste, touch, sight, and smell, especially smell, are well developed.

[1] It may be asked why the white asters were not the most conspicuous. The reply is that white, as a conspicuous colour in flowers, is not a success since so much white light is reflected by leaves and other objects.

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VIII

SCENTS

We have already seen that some moths possess an extraordinarily active sense which, with our somewhat limited experience, we can only describe as a sense of smell. It has also been pointed out that the odours which are given out by female moths, and by which the males are enabled to discover their presence, even at great distances, though faint, or more often quite imperceptible to us, may in reality be very powerful to organs specially constituted to appreciate them.

In calling attention to these 'directive' scents, as they may be called, we have merely touched the fringe of a much wider field of inquiry. The extent to which scents are employed in the economy of these insects increases in direct proportion to the care with which the phenomenon is studied.

Not only can the female produce the directive scent, but the males of many butterflies and moths are able to liberate a perfume the purpose of which can only be described as that of charming and attracting the female. Furthermore, both sexes of certain butterflies and perhaps of some moths have glands which produce, not attractive odours, but repulsive smells which are a protection against some, at least, of their enemies. We will describe an example of the latter kind first, since the organs

associated with the males' love-philtres are so complicated as to require more extensive description.

Few of the earlier workers have contributed more to the subject of scents and scent-organs than the late Dr. Fritz Müller, formerly resident in S.E. Brazil, and it is from his papers that I have taken one of the few examples yet studied of a special gland used for the production of a repulsive odour. The butterflies which possess this organ are members of a South American genus known as *Heliconius*, and also of some other allied genera. They are for the most part of a velvety black or blue-black, marked and banded with vivid colours, usually yellow and scarlet. Müller calls them the Passion Flower butterflies, since their caterpillars feed on various species of that plant. The source of the unpleasant odour is said to be different in the two sexes. In the male it appears to proceed from glands at the extremity of the abdomen, whilst in the female it is produced by two club-shaped organs protruded from the back between the last segment and the last but one, in addition to the glands. The club-shaped organ is set with scales which vary in shape according to the species, though these can only be seen after dissolving off the thick, sticky odoriferous substance in which they are entangled.

The more detailed examination of these organs is difficult in this country since proper microscopic investigation can only be made with fresh or properly preserved material, the dried examples we receive from abroad being useless for the purpose.

Just as the continuance of the race is more important than the occasional and inevitable loss of a proportion of

its individuals through 'enemy action', so we find that the apparatus evolved for the production of the male attractive scents is far more varied and complicated than that for repulsive purposes. The most elaborate organs of this nature so far known are the brushes and glands of the Danaine butterflies. The insects are rather large and very conspicuous forms, found commonly in the African and Oriental regions. The commonest, 'The Golden Danaid,' is deep golden yellow or orange-brown with black-and-white tipped wings. Others are black with a conspicuous white pattern. In all these butterflies the males have a pair of brushes hidden in the hinder end of the body. The form of these brushes is peculiar. It consists of a delicate bag, from the inner surface of which arise long hairs or bristles. The bag can be turned completely inside out by fluid pressure from within the creature's body. When thus everted the hairs stand out at right angles to the surface of the bag. The action may perhaps be better understood by imagining one finger of a fur-lined glove to be turned inside out, though the hairs in a butterfly brush are comparatively much longer than those of a fur glove. The everted brushes are quite conspicuous objects and can be seen when the insect is flying slowly. Fig. 46 shows the appearance of such brushes when expanded. They are impregnated with the scent and distribute it as the butterfly moves through the air. But whence comes the perfume? In some of the Oriental butterflies

Fig. 46. Diagram of the scent brushes of a Danaine butterfly extruded from the end of the abdomen.

there are glands at the roots of the brush hairs, and the scent, which appears to be in the form of an oily liquid, passes up the tubular centre of the hair, and escapes

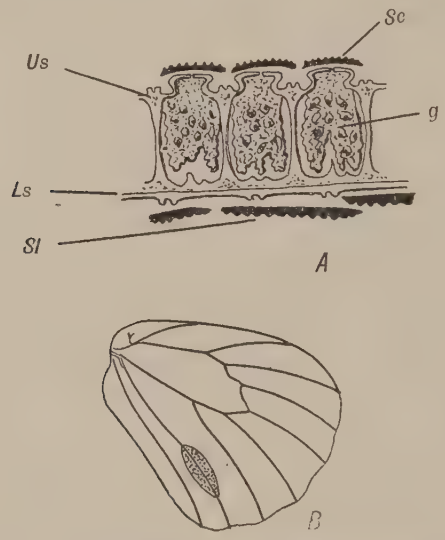


FIG. 47. The upper figure is a section, much magnified, of part of the scent patch in the hind wing of a Danaine butterfly. *Us*, the upper surface of the wing; *Ls*, the lower surface. The space between these is divided into chambers containing the scent-producing glands, *g*; *Sc*, the special scales covering the tops of the scent-glands; *Sl*, the ordinary scales of the lower wing surface.

The lower figure is an outline drawing of the hind wing showing the position of the scent-glands.

apparently by minute pores in the hairs themselves. This is, however, by no means the most usual arrangement. If male butterflies of the genus Amauris be examined in any collection, there will be seen on the

hind wing, near the body and towards the hinder edge, a little patch which has a slightly greasy appearance. If we cut out this patch from a fresh or properly prepared specimen, make very thin sections of it, and examine them with a microscope, we shall find a very elaborate structure (Fig. 47, *A*). The thickness of the wing is greatly increased and the space between the upper and lower membrane is divided up more or less regularly into compartments, each containing a cell or cells (Fig. 47, *A*, *g*) the special function of which is to produce the scent material. On the upper surface of the wing each compartment has a cup-like projection, though the cup is closed by a membrane, and the only exit is by a minute hole in its centre. Furthermore, each cup is covered by a special scale. These scales are smaller than the ordinary scales of the wing, and they are also much more firmly attached. The scent material doubtless oozes out through the minute pores and is retained by the special scales which cover them. What, then, is the connexion between the brushes and the scent-glands on the hind wings?

It is remarkable that Dr. Müller, more than fifty years ago, suggested the true explanation, and it seems somewhat of a reflection on the powers of observation of the average collector that not until 1911 was the action of the butterfly observed, by Mr. W. A. Lamborn, who actually saw the butterfly sweeping the scent-glands on the wings with the brushes in its tail. Careful examination of the brush in one of these, the Niavius butterfly, shows that it is composed of two different kinds of hairs. Part of the brush is of stiff black bristles, whilst the remainder is made up of more delicate silky hairs.

Apparently the stiffer hairs are used for scraping out the scent liquid, and the finer ones for diffusing it. It was not until very thin sections were made of these brushes that a new and remarkable fact was discovered. Certain cells in the brush bag produced delicate filaments, so fine that over ten thousand could be laid side by side in the space of an inch (see Fig. 48). These filaments have

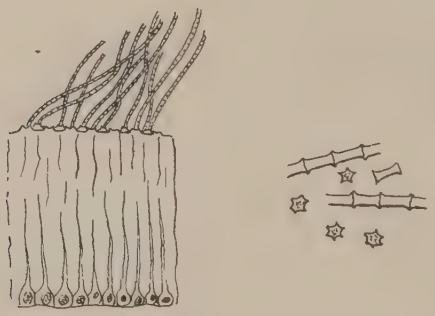


Fig. 48. A portion of the membrane of the brush bag of a Danaine butterfly with 'dust filaments' arising therefrom, and some of the dust filaments still more highly magnified showing how they break into minute particles.

a jointed appearance somewhat like cane, though the joints are relatively very much closer together. They break at the joints with the greatest ease, and the dust so formed is of extraordinary fineness. There can be little doubt that this dust becomes impregnated with the scent, and is scattered by the brushes. Indeed, the apparatus is really an animated powder-puff. Some time after this discovery Dr. G. D. Hale Carpenter actually saw a male of a nearly allied species hovering over the female and rapidly protruding and withdrawing

his brushes as though to scatter upon her the perfumed dust.

With suitable apparatus and a certain amount of skill it is possible to discover, by the method of section-cutting (see p. 44, note), the exact form of these scent-organs. It is by no means so easy to discover the precise function of each part of the organ. I have spoken of a form of brush which consists of stiff hairs, silky hairs, and dust-producing filaments. Such a form is amongst the simplest. In the Egialea butterfly we find a brush so complicated that only a careful examination of series of good sections will reveal its true form. At the bottom of the brush bag there arises a bunch of filaments having a very irregular section. They appear to be soft and liable to be altered in shape by pressure against each other. Moreover, they are solid. A little farther up the bag there arise filaments equally irregular in section, but these are tubular. Farther up still there appear the pale silky hairs and the stiff black hairs found in the other species, but these are separated by a layer of yet another form of irregular filaments. We thus have a brush made up of no less than five different kinds of hairs. Doubtless each has its own peculiar function, but what that function is we do not at present know. There is no sign of dust-producing threads in this brush, though the scent-glands in the wing are very similar to those in the other species described, the principal difference being that only alternate glands have openings to the exterior, and the scales covering them are much narrower and do not completely cover the glands. In the Ochlea butterfly some of the brush hairs develop minute nodules which become detached and so form dust in a manner some-

what different from that in the species having dust filaments; the quantity of such dust must be very small.

The formation of dust particles does not always take place in the brushes. In more than one species the scent-gland of the wing is in the form of a pocket or bag, and special cells in this produce delicate filaments which break into dust. There is, however, in some at least of these forms a further remarkable difference. The structure which in the mature butterfly appears as a bag is, in the pupal state, a flat, glandular area similar to those in the forms already described. In the act of expanding the wings after the insect has emerged from the pupa case, this patch is pushed out and so forms a small pocket. Even sections of a fresh wing did not show any cells giving rise to special dust filaments, though these were present in considerable quantity. It was only on making sections from a chrysalis that the secret was discovered. In the pupal state the cells are there, but before the butterfly emerges they have completed their function and become atrophied. The dust filaments are therefore limited in quantity, and but for the folding of the patch to form a sac they would all be rubbed off and lost at the first contact with the brushes. The sac, however, encloses them, together with scent-producing scales, the latter being like tiny bags of oil. Thus when the butterfly inserts its brushes into the 'scent sachets' on its wing, only a small quantity of the precious paste is removed at a time. Not all brush-bearing butterflies have dust-producing filaments. An Oriental species, the Midamus butterfly, has brushes, but no glands in the wing. In this species the scent is produced by glands in the brush bag itself, and at the base of the bag is a small

accessory vesicle, from the walls of which arise peculiar funnel-like sockets bearing delicate membranous tubes. Butterflies of the genus *Hestia*, large, white, delicate insects speckled with black, and sometimes known as 'ghost butterflies', have no wing glands but possess four tail brushes instead of two. The function of these is not very obvious, but probably one brush secretes the scent and the other acts as the distributor. Some of our common moths have brushes quite as large as those of the Danaine butterflies. They usually lie in grooves in the abdomen, and the grooves are lined with scent-scales. Scent brushes are not always situated in the abdomen of the insect. Many male moths have tufts on the legs which normally lie closely compacted in a special groove, but can be spread out fanwise at the will of the insect. Many male Skipper butterflies have a fold on the edge of the fore-wing, or patches on the middle of the wing, containing a scent apparatus. In our common Large Skipper this patch consists of a thickened portion of the wing containing glandular cells from which arise two different kinds of scales. One of these, greatly outnumbering the other, consists of a comparatively thick hair-like structure joined to its particular cell by an extremely delicate thread. The thicker portion develops slight constrictions, so that the whole filament when magnified has the appearance of a string of short sausages. Fracture takes place at the constrictions and so, once more, 'dust' is produced.

The other structure seems to be essentially the scent-producer, and is a long delicate thread, probably porous, and arising from a special socket in the wing membrane. These threads appear to be nearly smooth, whilst the

dust filaments are marked with delicate, curved ridges like a multiple threaded screw. (See Fig. 49.)

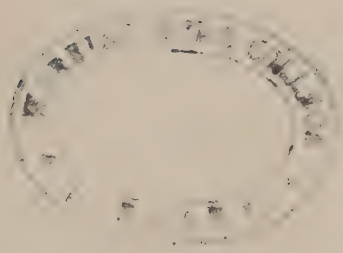
The commonest type of scent-producing organ is a special form of scale developed on the wings of the male butterfly, and such scales or hairs are to be found in many families and genera.

Fig. 49. The scent and dust scales from the scent patch of the common Large Skipper butterfly. The long thin scale, only a part of which is shown, is probably one of the scent-producing organs, whilst the others (only exceptionally short ones shown) break up to form the dust. (Magnified.)

Their most elaborate development is seen in what are known as the Pierine butterflies, to which our common 'Whites' belong. My friend Dr. F. A. Dixey has made a very special study of these scales and finds that even species may be distinguished by this character. The scents produced by these various organs are not all imperceptible to the human senses. If the reader will catch a male of our common 'Green Veined White', one of the earliest white butterflies to be seen in the spring, and will hold it gently between thumb and finger, and place his nose, if possible, between the wings, he will notice a strong scent of lemon verbena, the characteristic scent of this species.

Enough has been said to show that amongst insects, perhaps even more than other animals, scents and the power of detecting them are factors of the greatest importance in their economy. It is perhaps worth recording here that, in conjunction with Mr. Martin E.

Mosely, the author has lately investigated the scent organs in minute creatures of the genus *Hydroptila*. These little insects are allied to the familiar Caddis Flies well known to the fisherman. The insects are themselves no larger than the brush of a Danaine butterfly, yet they possess elaborately formed brushes, glands, and scent scales; the brush hairs are so delicate that over eight thousand side by side would barely measure an inch. The apparatus is situated not in the insect's 'tail' but in the back of its head, the head itself being only about the fiftieth part of an inch in width. The whole is enclosed when not in use by a pair of little flaps like folding doors, each barely visible to the unaided eye.



IX

BUTTERFLIES AND ANTS

THOSE who have made a study of the customs and habits of ants will tell us that in or about their nests there are to be found as guests, intruders, hangers-on, camp-followers, and in other capacities, many creatures other than the ants themselves. My friend Mr. Donisthorpe, whose knowledge of ants is varied and profound, has distinguished no less than 280 species of such aliens. This is not the place to describe all these varied associates, but certain butterflies are inseparably connected with ants, and some account of them must be given.

Of our British butterflies, one of the last to disclose its remarkable history is the Arion, or Large Blue, an insect only found in a few favoured localities in England. Many patient experimenters have endeavoured to solve the mystery of the Arion, and one must mention at least the late Dr. Chapman, Capt. Purefoy, and Mr. Frohawk as amongst those whose labours have been most successful. In early summer the female butterfly lays its eggs on wild thyme, and from these emerge tiny larvae which feed on the flowers, and owing to their pinkish colour are very perfectly concealed. So much has long been known, but efforts to rear the little caterpillars were never successful. About August they began to wander. Wild thyme lost its attraction for them and they pined and died. We cannot here repeat all the details of the

research which ultimately revealed the truth. It must suffice to give the whole story as it is now known. Like many larvae of the 'Lycaenid' or 'Blue' butterflies the Arion larva has a gland on its back from which exude drops of a sweet honey-like fluid, and this powerfully attracts the ants. On leaving the wild thyme our caterpillar begins to wander, and since it is always in the neighbourhood of the ants with which it is associated it is not long before it meets one by the way. Follows bribery and corruption, for the ant, so long held up as a

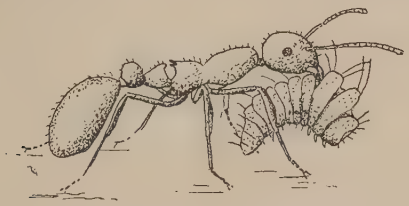


Fig. 50. An ant carrying away the larva of the Large Blue butterfly, magnified (after Frohawk).

moral example, is but a weak creature in the presence of temptation. The 'honey' appears and the ant helps itself. What happens next is difficult to explain. The larva adopts a new attitude. It raises its back somewhat after the manner of a hostile cat. It would seem that this posture is favourable to free transport, for the ant proceeds to lift the larva from the ground, and with much labour carries its living honey-pot bodily into its nest (see Fig. 50, taken from one of Mr. Frohawk's beautiful drawings). It may be that in times long past the free winter quarters so provided for the larva were repaid by further gifts of honey. However that may be, such fair dealing seems to have fallen into disuse, for our

experimenters tell us that once inside the nest the ants appear to take little or no further notice of the larva. But mark the depravity. Housed and protected for the winter, and hitherto a blameless vegetarian, it now becomes a carnivorous enemy. From August to the following April, with a midwinter period of rest, it feeds solely on the larvae of the ants. There is no doubt of its guilt since their mangled remains are to be found within it. When it was carried in, it was but an eighth of an inch long, but by April it has grown to its full size, perhaps about three-quarters of an inch, and burying itself in the soft earth it becomes a pupa, to emerge at the end of June as the largest of our blue butterflies. No wonder such an underground history took so long to unravel; but it is by no means singular. Lycaenid butterflies are associated with ants all over the world and many curious examples of this are now known. In Australia there is a comparatively large butterfly related to the 'blues' which we may call the Brassolis butterfly. It is dark sepia with orange markings. The female deliberately lays her eggs on trees infested by the 'Green' ant, one of the most ferocious of its kind. Whether the larva furnishes the ants with honey, and how it gets into the nests, does not appear to be recorded, though doubtless it is carried there by the ants themselves. Here it feeds on the ant larvae, and the pupa is found in the nest. Were the larval skin to be thrown off in the usual way, leaving a soft and defenceless pupa, it would speedily be devoured and the species could never have survived. To overcome this difficulty an entirely abnormal method has been evolved. The larval skin is hard and armour-like.

Why then discard so serviceable a garment? The pupa forms within the larval skin and so is protected. It lies like a nut in its shell. Precisely how the butterfly makes its way out of such a cocoon is not yet known, though the operation is carried out successfully. And now arises a new danger. The soft and tender butterfly would fall an easy prey to its voracious hosts. Until its wings have expanded it is very helpless, and yet this expansion must not take place too rapidly, for it has to make its way through winding paths to the outer world and full-sized wings would prevent its passage. Indeed, its wings at this stage are exceptionally small, and they take a full thirty minutes to expand. Even when expanded they are not dry enough for flight. Thus there is time enough for it to be eaten over and over again. Yet it invariably escapes. I have said that the butterfly is brown with orange markings, but this is its permanent dress. Freshly emerged it is white, the reason being that it has an overcoat of white scales on the top of its permanent covering. Legs, body, and antennae are all covered with this white fluff. Now ants dislike being 'messed up' with foreign substances, and 'messed up' they will be and that quickly if they molest our butterfly, for the white fluff comes off at a touch. So enraged do the ants become, and so intent on freeing themselves from the fluff, that they forget about the butterfly and concentrate on brushing down themselves and their companions. Safely into the open and with wings all ready for use the butterfly gives a few sharp flutters, all its white armour falls off like snow, and it appears in its true colours.

Many of the larvae of Lycaenid or 'Blue' butterflies

are carnivorous, and even those which are not so are liable to become cannibals when opportunity offers. As already mentioned, even the larva of our little Holly Blue will eat its companions at the moment when they cast their skins for the last time and appear as soft and defenceless pupae.

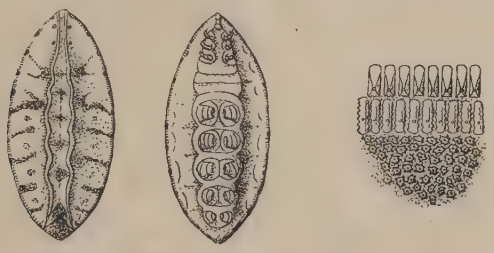
Some, however, are carnivorous all their lives, and one of the most interesting is that of the Zymna butterfly observed by my friend Mr. Lamborn in West Africa. On certain trees he found numbers of small insects related to our frog-hoppers. These are attended by ants which stroke them with their antennae and extract from them some secretion. The ants do not, however, eat the 'hoppers' themselves and indeed take great care of them, frequently building shelters over them. The hoppers do not object to the ants' ministrations, and though they can move with rapidity they remain passive under the stroking or tickling of the ants. Now this fatal complacency is the caterpillar's opportunity. It has learnt to vibrate its front legs in a manner suggestive of the ants' antennae. Slowly advancing on one of the hoppers it imitates the familiar caresses until it has secured a position well above its prey, when it suddenly bends down and seizes it with all its front feet. It bites first behind the unfortunate hopper's head and soon every particle is consumed. Mr. Lamborn adds, 'After the meal the legs of the first pair were drawn one after the other between the mandibles and then polished on the outer side of the face after the manner of a cat.' In seven hours one of these larvae was observed to capture and eat nine out of eleven of the hoppers provided for it.

In most instances of the association of caterpillars and ants the latter derive the benefit of a secretion from the

former, and the caterpillars obtain protection from their enemies through being surrounded by creatures which can bite or sting.

This exchange of advantages is evident in the history of the Arion butterfly already described, although the ants have not yet recognized, or if they have ignore, the destruction wrought by their guests.

A further example must be described, that of the



a *b* *c*

FIG. 51. *a*, View of the upper surface of the larva of the African butterfly *Euliphyra mirifica* (actual length about $\frac{4}{5}$ in.); *b*, under surface; *c*, magnified view of the edge of the 'mantle' showing the minute interlocking armour and the 'piano-key' formation of the edge.

Mirifica butterfly observed by Lamborn in West Africa. Some years ago larvae of this butterfly were handed to me for examination, and Fig. 51, *a*, *b*, *c*, are drawn from them and from microscopic preparations. The little creature is about four-fifths of an inch long, though probably larger when fully grown. It is very unlike a butterfly caterpillar, being indeed more like a small limpet (Fig. 51, *a*). Down the centre of the back is a double-waved ridge armed with tiny hooks, and the sides spread out like a mantle or shell which can be pressed

closely down all round. It is only when we turn it over that we find any resemblance to a caterpillar (Fig. 51, *b*). The head is very small indeed but is attached to a long neck which can be stretched out to some considerable distance. The whole surface of the back and sides is covered with minute hard plates. These form a most effective coat of mail. Round the edge of the mantle is a row of longer plates (Fig. 51, *c*) and, beyond these, very peculiar structures somewhat like piano keys, on the top of each being a delicate scale which probably acts as an organ of touch. Should the ant, also a species of the ferocious *Oecophylla*, attack the larva it can make no impression on the hard skin, and if it tries to get under the mantle edge this immediately closes down, fitting exactly any small irregularities in the surface on which the larva may be resting. Thus the ants, which would certainly tear it to pieces if they could, have no method of dealing with what may almost be regarded as a little animated 'tank'. Mr. Lamborn says that the larva lives in the ants' nests and that when the large workers are feeding the other ants by disgorging food into their mouths, the larva raises its mantle at the forward part, and folding it round so as to form a kind of tube thrusts out its head on the long neck already spoken of, and actually puts its head into the jaws of the ant, which feeds it. It is remarkable that though the ants frequently attacked the larva without success, they always fed it when in this attitude, without showing any hostility. There seems no evidence at present that the ants obtain any advantage from the larva, which, while it takes their food, at least does not, like the Arion butterfly, destroy their young. Mr. Lamborn found pupae in the

nests of the ants and also on leaves outside, and obtained the butterfly from larvae which he reared. If the butterfly commonly hatches out in the nests we do not yet know how it makes its escape without being attacked. It does not appear to be covered with white fluff like its Australian relative.

Mr. Dodd tells of a moth caterpillar in Australia which has a complicated association with ants. In its early stages it feeds on hoppers like the larva already described, but it soon makes a little cocoon under bark, from which it emerges again after casting its skin. It now adopts a peculiar attitude, turning its tail over its back, thus reversing the action of the Arion caterpillar. As soon as the ants find it they seize it and carry it off to their nests. In this instance the larvae not only supply the ants with a secretion of which they seem very fond, but they lick and brush down the ants which come to them for this purpose. In return for these services of cook and valet the caterpillars take toll of the ant larvae, the ants either tolerating or ignoring their raids. Apparently the larvae either by accident or intention wander out of the nest, especially in the early morning, for Mr. Dodd has observed these 'constitutionals', and has seen the ants carefully carrying their charges back again. On one occasion he saw a larva make four such excursions in succession, only to be relentlessly returned to its prison. In due time it is ready to become a chrysalis and for that purpose it leaves the nest once more. Now, however, the ants do not carry it back, but escort it to some crevice on a tree, where it spins a cocoon, and as a farewell gift sometimes emits, while spinning, a last drop of its delectable secretion. Very many caterpillars are

known to be associated with ants, but in the majority of instances the bargain seems to be limited to protection in return for the contents of the so-called honey-gland. The instances I have quoted are examples of more complicated relationships, in some of which the caterpillar seems to have solved the problem of gaining the protection of a fierce and dangerous host, without suffering for its temerity or giving anything in return.

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X

CONCEALMENT, MIMICRY, AND POLYMORPHISM

We have already made a preliminary acquaintance with certain forms of mimicry in which caterpillars and pupae so closely resemble their surroundings, or inanimate objects which are of no interest to their enemies, that they are extremely difficult to detect. The perfect butterfly or moth is often found to be so coloured and shaped that when at rest it becomes unrecognizable. One of the most frequently adopted devices is that in which a resting insect resembles a dead leaf. Such a resemblance is found in perhaps its greatest perfection in the well-known 'dead-leaf butterfly' (*Kallima*) of the Oriental region, a common object in many museums.

It is remarkable that the discovery in a museum of a case containing examples of this butterfly is hailed with all the surprise of novelty as one of the marvels of exotic insect life, when in fact one need go no farther than an English garden to find examples of the same method of concealment, certainly not quite so perfect, but nevertheless quite unmistakable in intention.

Our Brimstone butterfly at rest with its wings closed, all the Vanessid butterflies, such as the Tortoise-shell, the Peacock, the Red Admiral, and especially the tattered-looking Comma, with the small curved mark like a crack in a dried leaf, are most difficult to observe when their wings are closely pressed together, and though with the

exception of the last-named none of these can be said definitely to imitate a leaf, nevertheless they are leaf-like in appearance and in suitable surroundings are extremely well hidden.

Our coloured plate shows a few of the butterflies which illustrate this particular method of concealment. I have figured the Purple Emperor, the Red Admiral, and the Comma butterflies.[1] As they appear there with wings expanded nothing could be more conspicuous, but here we see only the upper surface of the wings. Compare this with the figures of the same insects at rest, the wings closed and only the under sides visible. It is easy to realize from these illustrations how in life and against a natural background they seem to vanish completely though actually still exposed to view. Of the Kallima butterfly, already referred to, the late Alfred Russel Wallace wrote: 'I have watched it settle apparently in a very conspicuous situation, a few yards off, but on crawling carefully to the spot, have been quite unable to detect any living thing. Sometimes while gazing intently, a butterfly would start out from just before my eyes, and again enter another dead bush a few yards off, again to be lost in the same manner.'

One of the most remarkable 'dead-leaf' insects is a Trinidad moth shown at Fig. 52. In this the outline of the wings is such as to make them appear tattered and torn; the colour above is dead brown, and below there are dark markings resembling the growth of some fungus. But the crowning feature of the deception consists in the presence on the wings of transparent patches interlaced with lines so as to give the appearance of

[1] The figures are about $\frac{3}{4}$ natural size.

a partly skeletonized leaf. I have been unable to learn any details of the habits of this moth beyond that it is probably a night flier, and that the example figured was found on the ground. If during the day it habitually rests on the ground, it would seem to matter little whether it does so with its wings expanded or raised above the body ; either way it would be unrecognizable as a moth.

Many of our British moths, though not expressly imitating leaves, nevertheless adopt when at rest attitudes which give them a more or less leaf-like appearance.

Fig. 52. A Trinidad moth (*Draconia rusina*) resembling a skeletonized leaf.

Both the Lime Hawk and the Poplar Hawk adopt such an attitude, while the Lappet moth is well known to collectors from its habit of hanging by the fore feet with the margin of the hind wings projecting beyond the fore wings, its whole appearance resembling a bit of dead and brown vegetable débris.

Resemblance to leaves is not by any means the only disguise adopted by butterflies and moths. In South America are found the great Caligo butterflies, the undersides of which are beautifully lined and shaded so as to resemble the overlapping feather tips of an owl, and on either side is a huge eye-spot, so perfectly simulating an

eye that even the reflected light dot is clearly represented.

Very many moths have transparent wings and are so shaped and coloured as to resemble bees, wasps, hornets, and other insects which have a well-earned reputation for their offensive powers. Even our British Hornet moth is quite sufficiently like a hornet or large wasp to deceive the inexperienced, whilst some of the exotic forms imitate even more perfectly the types of stinging insects. In most, if not in all, the effect is enhanced by the convulsive movements of the abdomen so suggestive of the presence of a concealed weapon.

We have seen then that these insects may resemble either objects in which their pursuers take no interest, that is, the resemblance tends to concealment, or they may resemble insects of other orders which their enemies have learnt by experience to leave alone. Here there is no attempt at concealment. Indeed, the bolder the advertisement the more likely it is to deceive and the more effective its protective power.

Bearing these facts in mind, we may ask whether there are any butterflies which possess in themselves some positive protective quality. Are they all as delicate and defenceless as they seem? Some are slow flying, very conspicuous, and seemingly careless of pursuit; they would seem to be an easily captured meal for insects, birds, and other insectivorous creatures; yet they are abundant. The reply is that many of these careless, unwary butterflies do possess a certain degree of protection. They are unpleasant to the taste of those creatures which would otherwise consume them. This fact was suspected and adopted as a theory long before

its truth was established by observation and experiment. If then there are butterflies and moths which enjoy some degree of protection by reason of their unpleasant flavour, other butterflies and moths, not in reality inedible, would derive no small benefit, could they resemble in colour and pattern these more fortunate species. And indeed there are so many examples of more or less perfect imitation between widely separated species that the subject has become a great and complex study, the full discussion of which would fill many volumes. Nevertheless, the present account of butterfly lore would be incomplete without some mention of these beautiful mimetic forms.

Even an outline of the history of the study would occupy too much of our space, and it must therefore suffice to say that in 1861 the great naturalist Bates was the first to call attention to the wonderful resemblance between butterflies of different families, and at the same time to suggest an explanation. He noticed that the Heliconius butterflies of South America were accompanied by others belonging to such different families as the 'Swallow-tails', the 'Whites', and even many kinds of moths, all of which, while departing widely from their usual family patterns, had adopted the very different and striking livery of the Heliconius. The explanation he offered was that the latter, which were numerous, careless of pursuit, and apparently but little attacked, possessed some property such as distastefulness which accounted for their comparative safety, and that the others benefited from the evil reputation of their models. In this way was established the theory since known as Batesian mimicry, the supposed conditions of which were that

a distasteful species, very numerous by reason of its protection, was accompanied by smaller numbers of other and widely different species, which though in reality perfectly edible, escaped destruction owing to their outward resemblance to their unpleasant models. Soon, however, a new difficulty arose. It was observed that different species of distasteful butterflies mimicked each other, and of this phenomenon no explanation was afforded until Müller in 1879 pointed out that if there were two kinds of butterflies, both distasteful and of quite different patterns, we might suppose that a certain number of each would be sacrificed to the experimental tasting of inexperienced enemies. Suppose further that each species lost 100 individuals in this way, 200 butterflies would be destroyed. If, however, the two species were so similar in appearance as to be mistaken for one another, 100 casualties would still suffice for the enemies' education, and hence each species would lose only 50 individuals. It would thus be a great advantage that the two species should resemble each other, since their losses would be halved. Such is an extremely simplified statement of what has since been known as Müllerian mimicry. Probably no such simple case occurs in Nature; it supposes a practically equal number of the two species, and many other definite factors which would rarely occur singly and probably never in combination.

Moreover, there are certain difficulties, not perhaps insurmountable, in that first approach in pattern between two very dissimilar forms. Furthermore, the division of cases of mimicry into two definite categories, Batesian where an edible form mimics a distasteful, and Müllerian where two distasteful forms mimic each other, does not

take into account the undoubted existence of degrees of distastefulness. From many experiments, and especially those recently published of Mr. C. F. M. Swynnerton, we know that there is probably no such thing as absolute distastefulness.

The degree to which a butterfly may be destroyed and eaten by its enemies, especially by birds, depends on the state of the destroyer's appetite for the time being. A very hungry bird will eat certain kinds of butterflies which, less ravenous, it will promptly refuse. All manner of factors will affect the result, such as the presence or absence in a given neighbourhood of a sufficiency of other and more palatable food, seasonal differences in the supply of food, and entirely outside factors affecting the numbers and activities of insectivorous enemies.

Enough has been said to suggest the great complexity of the subject, and to show the impossibility of discussing it fully in a work of the present character. Complex as these forces are, they have undoubtedly produced the most wonderful resemblances between butterflies and moths of widely different families and genera, and at once we must make it very clear that such resemblances are purely the result of natural selection.

The term mimicry naturally suggests in the minds of those unfamiliar with these subjects some sort of conscious action on the part of the insects concerned. Nothing of the kind is implied. The insect has probably no knowledge of its own pattern, and certainly none concerning any benefit that could arise from changing it. Still less could it change it if it would.

There is a constant tendency amongst living creatures to produce variations from the existing type. If such

variations are in any way beneficial to its continued existence, they will afford it some advantage in the struggle for life. Thus it may be more likely to survive to the point of reproducing its kind, and the beneficial variation may continue in its offspring. These again may vary still further in some still advantageous direction, and the best of them again produce offspring. If the struggle is keen and continuous we may see how a small but recognizable variation may be elaborated into an increasingly close resemblance between an unprotected and a protected species. The difficulty experienced by many otherwise thoughtful minds in grasping the great process of evolution by natural selection is largely due to the still common belief in the idea of the spontaneous creation of all creatures just as we now see them. Were such the truth the geological record would be the most stupendous lie ever enacted. The ever-present variation in living creatures is frequently overlooked, and mainly for the reason that it is seldom realized that only the favourable variations survive. The inappropriate variations, that is, the overwhelming majority, have been ruthlessly destroyed and are extinct.

Unfortunately mere descriptions can do little to give an adequate idea of the prevalence of mimicry in butterflies, especially in those of the tropics, where reproduction is rapid and the struggle for existence continuous. Indeed, some knowledge of classification is necessary before we can realize the significance of the remarkable resemblances which occur between so many different species.

Some account of a few well-known instances may, however, be given, and as a further introduction to a great

subject I can only refer the reader to my previous work, *African Mimetic Butterflies*, in which over one hundred and sixty examples are illustrated in colours. Having gained some insight into the rudiments of the matter, he should then consult the many works of Professor Poulton, F.R.S., who, by his patient labours and illuminating discussions has made the subject a great science in itself.

Probably all butterflies may be regarded by the uninitiated as very closely allied, and a resemblance between two or more species will seem in no way remarkable. It must be understood, however, that they are divided into several families and very many genera, and that though they are all butterflies there may be considerable differences in their anatomy, life-history, and habits. In Birds, for instance, a Hawk and a Pigeon are very different, and were we to discover a bird which according to its anatomy was really a pigeon, but which through some purely deceptive colouring, or some other *outward* character, had almost the exact appearance of a hawk, we should consider some explanation necessary. With regard to the butterflies which experiment has shown to be unpalatable to insect-eating animals, the cause of this unpalatability may be clear even to our own senses. They may have a nauseous smell like the Heliconius butterflies already mentioned, or they may, when captured, exude an acrid juice as do the Acraeine butterflies of Africa. A very hungry bird will eat one or two such insects but soon refuses more. An experienced bird or other animal will pick one up but throw it away again often with clear signs of disgust. And here arises a remarkable fact. These unpleasant kinds are generally

tough and less liable to injury. Thus they may escape even after being the subject of experiment. That such butterflies are less subject to persecution by capture than others is shown by the fact that they usually fly more slowly and are less alert. Selection has preserved the habit of display or advertisement. One of the commonest of these unpleasant species is the Golden Danaid already mentioned, with conspicuous black-and-white tips to the fore wings. Like most of its kind, it is conspicuous and easy to recognize; and it is very widely mimicked. Wherever it is found, other butterflies, not in any way related to it, have evolved a pattern and colour likely to be mistaken for that of their model. In Africa and parts of Asia its best-known mimic is the Misippus butterfly. The family characteristics of *misippus* are black wings bearing large central white spots ringed with shot blue or purple. The male is true to tradition and bears this pattern. Not so his mate, who has evolved the golden brown or yellow, and the black-and-white tips of the Danaid and so has no resemblance whatever to her spouse.

Furthermore, the Danaid has more than one livery. In some districts it has lost the black-and-white tips so that its wings are of a uniform deep yellow. The female *misippus* has developed a copy of this. Though the white has disappeared, the place where it should be is paler yellow than the rest, and so the ghost of her former pattern can be seen, outlined also with a sprinkling of dark scales, the last remnant of the black tip. The Danaid has still another form especially common in West Africa. The greater part of the hind wing instead of being yellow is white, and there is a form of *misippus* which

has developed the same variation. In these two species the models and mimics are not always found together.

Sometimes a mimicking butterfly may have a wide range, as for instance from the East to the West coast of Africa. A convenient model may not have so extended a habitat, and in the small Alciope butterfly we have an example in which the female imitates one model in West and another in East Africa, so that the male, which does not change in this way, has two different females according to whether he is a native of the East or of the West side of the continent.

No account of mimetic butterflies would be satisfactory without mention of the Dardanus butterfly, which Professor Poulton has justly called the most wonderful butterfly in the world. Its history would fill a volume. It is found both on the African continent and on the island of Madagascar. On that island the male and female are nearly alike; large cream-coloured swallow-tailed butterflies with black tips and borders. This may be regarded as the ancestral condition. On so ancient an island the struggle for life has doubtless achieved something like a balance, but *dardanus* exists also on the mainland of Africa. That it has survived there appears to be due in no small part to its inherent instability of pattern, at least in the females, combined with a remarkable versatility in the power of variation. On the mainland there are many butterflies of distasteful properties and of a size to serve as models for the Papilio, but they are not 'Swallow-tails'.

Now here the female has contrived to lose her 'tails', though occasionally examples are found with the rudiments of these still evident. Widely distributed, she has

established herself over the greater part of tropical Africa, and naturally the Danaine butterflies whose patterns she has copied are not the same over the whole range. Indeed, they are of many forms. The deep yellow Danaid butterfly already mentioned is one of them, and there is a female *dardanus* having this pattern. A great black-and-white Danaid occurs both in East and West Africa, though the Western examples are blacker than those from the East. The female *dardanus* has a dress to match both. In other regions there is a black Danaid with white spots on the fore wing and a yellow patch on the hind wing. This again is faithfully copied by the now tailless female of our 'Swallow-tail'. One of the Planemas, an Acraeine butterfly known to have unpleasant properties, is a beautiful creature with orange and white banded wings, and again the female *dardanus* appears in the same disguise.

At Oxford there is perhaps the greatest collection in the world of the forms of this protean butterfly, including many families which have been bred from eggs. At times several different forms of female have been bred from the same mother. In my previous work, already referred to, I illustrated fourteen different forms of the female of this butterfly and many more have since been discovered. Intermediates are of frequent occurrence, and in the great collection referred to the whole history of the development of these mimetic patterns can be traced from a primitive form, sometimes with rudimentary tails, found on the Kikuyu Escarpment. This butterfly is a self-contained illustration of the theories of evolution, selection, and mimicry. Several of the female forms were known to collectors long before their true relation-

ships were discovered. The late Roland Trimen noticed that these forms were invariably female, whilst the cream-and-black Swallow-tail was always male. In those days it required the courage of genius to proffer the suggestion, not merely that one of these forms was the female *dardanus*, but that all were female forms of the same butterfly. By some notable collectors of the day his suggestion was received with something more than contempt. Apart from breeding experiments already conducted by Mansel Weale and Leigh, an interesting confirmation of Trimen's theory came in a most unexpected manner. Occasionally butterflies are found which present some of the characters of both sexes. They are known as Gynandromorphs. One such was received at Oxford. It had the appearance of the orange-and-white banded form of female *dardanus*, but here and there the cream-coloured scales of the male and part of its pattern were to be seen on the wings. It is a great satisfaction to know that Trimen lived to see some of the bred families now in our possession and to enjoy the fulfilment of his shrewd prognostication.

Such multiple forms are not always confined to female butterflies. Both sexes of the same butterfly may occur in two or more forms which long after their discovery were thought to be quite separate species. Thus in Africa there is a species which occurs in at least four and probably more quite different forms, though such differences of colour or pattern do not indicate the sex. It may be a black butterfly with large white areas on both wings, having a pearly iridescence; it may have a very narrow or a very broad black border on the hind wing; the white of the fore wing may be reduced to spots,

whilst still another form may resemble this but the white of the hind wing is replaced by yellow. Each of these forms closely resembles a dominant distasteful Danaine butterfly with which it flies. It is only in recent years that experiment has shown that such different forms may be produced from the same batch of eggs. It must be understood that these polymorphic forms differ only in colour or pattern; they are identically the same species, whilst from the models which they resemble they differ in important points of anatomical structure.

Their resemblances to their models are not due to relationship but to purely outward changes of comparatively recent development. Other and highly complicated instances of mimicry are now known, but to enumerate them without pictorial illustration would prove tedious. Dr. G. D. Hale Carpenter has proved the influence of distasteful models on butterflies of unstable pattern. On the mainland of Africa there is a butterfly which has several well-defined forms, almost all of which resemble distasteful species with which they fly. Intermediates are rare. On the islands in the great Victoria Lake the models are absent or scarce. Here the variable butterfly runs riot, the patterns are unstable and intermediates very common.

Professor Poulton has pointed out a very interesting fact connected with mimics and models. The pattern of a species which has long served as a model is usually well defined. If for instance such pattern consists of a coloured band across the wing, the edges of the band will be clearly cut and distinct. Species which mimic this pattern have the band generally somewhat blurred at the edges, pointing to more recent development and

present instability. Another interesting discovery bearing on the same point was made by Mr. W. J. Kaye. The South American genus of butterflies, *Heliconius*, previously referred to, can be divided by a certain characteristic into two sections. It is a peculiar fact that the members of section A consist of very few species, but develop a wonderful series of forms, each of which closely resembles some other butterfly, often a member of section B of the same genus.

Now in this section B is a black butterfly with certain red markings, and it has a faithful attendant from section A closely resembling it. In fresh specimens the imitation is very close, but after some years certain of the red marks in the 'mimic' fade, whilst those of the model do not. It is evident that part of the red in the mimic is recently acquired, and actually of a chemical constitution different from and less stable than that of the older red marks.

The arguments against the theory of Mimicry, or perhaps we should say against the reasons assigned for the admitted resemblances, are neither numerous nor powerful.

The first is of little importance. It is that of the diminishing number who reject evolution in its entirety, and seek to maintain that all forms are now as they always were; in other words it is the doctrine of spontaneous creation. The study of butterflies alone provides complete proof that changes have taken place in patterns and colours as well as in structure and form. No conscientious student of comparative anatomy could long be a disbeliever in evolutionary adaptation. The late author of the *Insecta* in the Cambridge Natural History, in referring to the subject of mimicry in insects,

ventures the statement that there is no evidence that the alleged mimicking patterns were ever other than they now are, and yet a short inspection of even a small collection of mimetic butterflies would have saved him from so unfortunate a misstatement.

Since birds are suggested as powerful agents in that process of natural selection which has assisted in the development of mimetic patterns, the opponents of the theory are always anxious to assert that, once again in the words of the author above quoted, 'Birds have been but little concerned in the matter'.

They point out that if birds were such important factors they would be constantly seen to attack butterflies. Recent experiment has however shown that it is difficult to see what birds do eat; but by careful observation they may often be seen to attack butterflies. Those who maintain the contrary seem oblivious of the fact that were their statements true it would be some evidence of an altogether too perfect development of protection in the insects.

But, say these critics, great numbers of birds' stomachs have been examined without finding the remains of butterflies. The question immediately arises, how have they been examined? The digestion of a bird is very rapid. The writer has examined the contents of the stomach of a bird which was shot soon after it had been seen to eat butterflies. Only a careful microscopic examination showed traces of scales and macerated particles. Even the hard proboscis had been reduced to powder, so that small fragments only could be recognized.

Another argument is that climatic or other external

conditions produce resemblances. But this takes no account of the fact that often only the female, whose life as the egg-producer is so important, develops a mimetic pattern. But surely the climatic and other external conditions are the same for both sexes.

It is further pointed out that butterflies which do not mimic others survive and may even be common, therefore why cannot the mimics survive without their special subterfuge?

Here again is evidence of a limited outlook. Those species which survive obviously have means to defeat their enemies, or they would speedily cease to exist. The greatest advocate of mimetic theory would not claim that mimicry was the sole defence open to butterflies. Indeed universal deception must soon cease to deceive. The scientific worker is ever ready to abandon any theory once it can be proved that it is defective. The existing theory of mimicry, whilst it may not account for all known facts connected with the phenomena, accounts for many more than any other suggestion so far advanced.

Criticism of any theory is, however, in every way desirable. Different points of view should be carefully considered and their value weighed. Only in this way can truth, the aim of all scientific work, be attained.

The title of this chapter includes the word polymorphism. It signifies the property of having several or, more accurately, many forms. Dimorphism is another word used in the same connexion and signifies the property of having two forms.

Thus the Alciope butterfly already mentioned has two different females, and that sex is said to be dimorphic.

The female *dardanus* is polymorphic. Polymorphism is not always confined to the female sex. Undoubtedly the great majority of cases of polymorphism in one or both sexes are associated with mimetic patterns, but there are examples in which change of form occurs owing to causes which are not yet understood. Thus the African Pseudolycia butterfly is scarlet with orange-and-black markings when found on the East Coast. Farther inland and across the Congo Region the scarlet gradually gives place to an increasingly dull colour tending to brown, whilst in Angola the same butterfly, though retaining its orange-and-black markings, is in other respects white. Needless to say these forms were at one time regarded as entirely different species, until careful anatomical examination proved them to be the same. Such forms are known as geographical variations, or races.

Another example of change of colour pattern is that known as seasonal dimorphism. The same species of butterfly does not always present the same appearance at different times of the year. By this we do not mean that the same individual changes its colours, but that the offspring of one form, produced at a different season, may not resemble their parents, whereas the later generation born in the corresponding season will return to the form of the grand-parents. Perhaps one of the best examples is that of the African butterfly whose two forms are known as *sesamus* and *natalensis*. The former is a dark-blue butterfly, while the latter is salmon-red. They were naturally regarded as quite different species till Dr. G. A. K. Marshall showed by most painstaking experiments that the one form produced the

other, and that the dark-blue form is associated with the 'dry' season, or tropical winter, whilst the red form is produced in the 'wet' season or summer. This example is the more remarkable since wet season forms are usually darker than those of the dry season. Marshall, Merrifield, and other experimenters have shown that these changes of form can to some extent be induced by artificial conditions of temperature and moisture. Apart from mimicry, seasonal and geographical forms, the two sexes of the same species may be quite different in appearance. This is known as sexual dimorphism. Strictly speaking, where an animal has two sexes [1] they are always dimorphic since they necessarily differ in their sexual attributes, but the term as applied to butterflies usually means a sexual difference in colour or pattern or both. This condition is well illustrated in the great East Indian 'Bird Winged' butterflies or Ornithoptera. The males, though smaller than the females, are usually black with bands or patches of metallic green, orange, blue, or iridescent gold, whilst the females are nearly all of a dull sepia colour with paler markings. An example of the same phenomenon in our own country is the beautiful little Orange-Tip butterfly, the female of which has none of the flame orange colour which distinguishes

[1] To those who have not made a study of Natural History it may come as a surprise that there are animals which have not male and female forms. Thus a snail cannot be said to be either male or female since each individual combines the attributes of both, a condition known as hermaphrodite, and common in many lower forms of life. In other cases animals are known which produce males only occasionally, many generations of self-fertile females being produced in the intervals. Thus the common rose aphis or 'green-fly' produces a constant succession of self-fertile females during the summer, and, what is still more remarkable in an insect, the young are born alive.

the male. Birds furnish many examples of the same sexual differences, and the peacock will readily occur to the reader as a familiar example.

The naturalist, who almost of necessity must be an evolutionist, sees in the development of form, pattern, colour, and habits, a gradual adaptation to changing circumstances. The patterns of butterflies' wings are, as we know, not fixed and permanent. Variations occur, and favourable varieties may be developed and temporarily established. It is in the study of mimetic patterns that so many examples are to be found of adaptation and the development of new forms.

In North America there are butterflies related to our White Admiral. One of them, known as the Viceroy, has so far departed from the ancestral colours of its race as to resemble the Monarch, a butterfly of very different subfamily, and an immigrant from the Old World. This example has been aptly utilized by Professor Poulton as a powerful argument against the idea that mimetic patterns are produced by local conditions. Were this so, the immigrant Monarch would have changed its pattern, and not the indigenous Viceroy. But it may with truth be said that whilst mimicry in butterflies furnishes indications of the evolution of certain patterns and colours, it supplies no evidence of the evolution of new species.

Nevertheless, the study of butterflies from another aspect does supply evidence of certain ways in which new species may be evolved. There are certain forms which are found only at considerable elevations. Presumably something in their constitutions has been adapted to these conditions so that they do not now thrive at lower levels.

On Mount Mlanje in Nyasaland and on Mount Chirinda in S.E. Rhodesia are found certain black and white butterflies. So closely do they resemble one another that it would be difficult to say which of two given examples came from the one or the other locality. Usually the specimens from Mount Mlanje are without certain delicate black lines on the under side of the hind wing, such lines being present in the Mount Chirinda specimens. If both were found in the same locality such a fine difference would be probably regarded merely as an unimportant variation.

Careful anatomical examination shows, however, that the Mount Mlanje examples are developing a difference in anatomical structure which, carried a little further, would probably preclude effective mating with specimens from Mount Chirinda. Here we have an example of a species in process of formation. At present the two are practically the same, but geographical isolation is permitting in one colony the development of features not adaptable to those of the other.

Again, we have a series of forms extending across Southern Tropical Africa. The same anatomical investigation shows that individuals from adjacent areas might mate together, so that the whole series of forms constitutes a kind of chain of affinity, but the structure of the extreme eastern and western forms differs so widely, through the accumulation of slight differences, that the individuals at each extreme may be regarded as different species. The pattern has kept pace with the other changes, and the outward appearance of the eastern and western individuals is very different.

It is only in recent years that studies of this nature

have been developed, but already such researches are bearing fruit and their value becoming recognized.

The subjects briefly referred to in this chapter could be discussed at great length since they form in themselves a wide field of study, but mere descriptions without coloured illustrations can convey but little idea of their interest, and less of their significance in the study of heredity and evolution. They furnish at least a partial reply to the question, 'What is the use of the study of butterflies?' But the answer is too long to be expressed in a few words, and too wonderful to be inadequately attempted.

Unfortunately, only those who have been privileged to study Natural History in its relation to the problems of life and form, can realize how rich and significant is the field opened up by the investigation of the patterns and life-histories of butterflies. To many, the theory of Evolution is still a peculiar and even unorthodox idea, having some obscure sort of bearing on the development of living creatures. To those whom the study of living forms has convinced of its truth, it is a scheme of constructive progression far excelling in grandeur and moral worth the old traditions of spasmodic and independent existence. Evolution, as Burke said of Geography, may be an earthly subject, but it is a heavenly science.

We have now traced the butterfly through its life-history; we have inquired into the secrets of its structure and senses, its love-making and weapons of defence. We have seen something of its place in nature and of the dangers which constantly beset it; something too, we have observed, of the subtle arts by which (for the present at least) it is maintaining itself in a hostile world. Of

recent years much has been done to solve the problems of butterfly life, yet much remains. Because a given species has long been familiar to collectors, it by no means follows that its habits and history are fully known and understood. The country lover may well find an increased pleasure and interest in his walks afield, when he remembers that opportunities to enrich knowledge are still open to patient observers. He would do well to bear in mind that the handmaid of observation is record. Gray, who was both observer and poet (if it is permitted to distinguish between the two), has a shrewd note on this: 'Half a word fixed upon or near the spot is worth a cartload of recollection.' But quite apart from the fascinating possibility of discovery, the loving observation of nature has its own peculiarly unique value in rejoicing the eyes and making glad the heart.

> Nature never did betray
> The heart that loved her;

True! and even less than the whole truth. For Nature—if one may venture to adapt one of the most treasured phrases of the great high-priest of English nature worshippers—never fails to support and uplift the humblest of her lovers.

The peaceful old gentleman referred to in our earlier pages may or may not have been suggested by the memory of his more famous ancestor, of whom the inimitable author of the *Ingoldsby Legends* wrote that

> Black-beetles and Bumble Bees,—Blue-bottle Flies
> And Moths were of no small account in his eyes.

The pioneer falls by the way but knowledge progresses.

Had not that unfortunate inquirer come to so untimely an end in his own pond, he might have lived to tell us that bees largely control our fruit crops, and that 'blue-bottle flies' may carry on their restless persons dangerous diseases. Since he was drowned in a pond he was doubtless familiar with gnats, and would have been especially interested in the control they have exercised over some of our greatest engineering efforts. Alas, his views on butterflies are not recorded. And what of those who read these pages? Is it too much to hope that these delicate creatures, rivalling even birds in their exquisite forms and colours, may have secured for themselves something more than a mere aesthetic admiration in the minds of those who have patiently followed this book? I am not without hope that some at least of my readers may even be brought to seek and to find the great and abiding reward of the true naturalist:

> Swift bird and beast and jewelled insect free
> Trust me full well; one brotherhood are we.

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Printed in England at the Oxford University Press

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